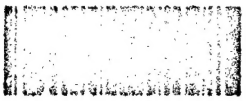

PB93-221794

Chemical (Atmospheric) and Biological Measurements in Panama Volume 1. General

National Center for Atmospheric Research, Boulder, CO

Prepared for:

National Science Foundation, Washington, DC

Aug 73

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NCAR-TN/STR-88 Vol. I
NCAR TECHNICAL NOTE

August 1973

PB93-221794

Chemical (Atmospheric) and Biological Measurements in Panama

Volume I: General

John B. Pate, NCAR
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ATMOSPHERIC QUALITY AND MODIFICATION DIVISION

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
BOULDER, COLORADO

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Abstract: This report series (Vols. I-V) presents the chemical measurements made by the Atmospheric Chemistry Group of the National Center for Atmospheric Research (NCAR) for project, Trace Chemistry of Tropical Atmospheres, supported in part by the Army Research (ARO), Durham, N.C. (contract DAHCO4 67-C0024). The study was conducted from Febru 1965 to January 1970, while the Atmospheric Chemistry Group was part of the NCAR Labo of Atmospheric Science.

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FOREWORD

This report series (Vols. I-V) presents the chemical measurements made by the Atmospheric Chemistry Group of the National Center for Atmospheric Research (NCAR) for the project, Trace Chemistry of Tropical Atmospheres, supported in part by the Army Research Office (ARO), Durham, N.C. (contract DAHC04 67-C0024). The study was conducted from February 1965 to January 1970, while the Atmospheric Chemistry Group was part of the NCAR Laboratory of Atmospheric Science. The report series also includes the chemical and biological measurements made by the U.S. Army Tropic Test Center (USATTC) for the project, Environmental Data Base for Regional Studies in the Humid Tropics (also referred to in this report series as the Data Base Program), sponsored by the Office of the Secretary of Defense, Advanced Research Projects Agency (ARPA), Directorate of Remote Area Conflict, and by the Department of the Army, Office of the Chief of Research and Development, Army Research Office, Washington, D.C. This study has also been published as USATTC Technical Report No. 7109001.

The chemical and biological data in this report series are combined with soil and meteorological data to form an environmental data bank consisting of measurements made in Panama in the Data Base Program. Copies of this data bank are deposited at Headquarters, U.S. Army Test and Evaluation Command, Aberdeen, Md., and at the Earth Sciences Division, U.S. Army Engineer Topographic Labs, Fort Belvoir, Va.

Volume I of this report series describes the project and the 34 sampling sites used for chemical and biological sampling (most of which are in the Canal Zone).

Volume II describes the methods used in sampling and analyzing atmospheric trace gases and includes tabulations of all gas data. Gases measured were sulfur dioxide, nitric oxide, nitrous oxide, nitrogen dioxide, ammonia, aliphatic aldehydes, and hydrocarbons.

Volume III describes the methods used in sampling and analyzing particulate matter and includes tabulations of all particulate data. Measurements included size distributions of chloride- and sulfate-containing particles collected on membrane filters, mass of particles on Nuclepore and glass fiber filters, optical density of particles collected on paper tape and in spore traps, mass of formaldehyde-containing particles collected by impaction, and percentages of morphological types collected by impaction.

Volume IV describes the methods used in collecting and analyzing biological samples and includes tabulations of all such data. Measurements were made of surface depositions of microorganisms, concentrations of airborne microorganisms, accumulation of litter, numbers and types of flying insects, and nitrogen content of flying insects.

Volume V provides full information on storage and retrieval of data from the data bank, and describes the coding used for each type of data.

References for each volume are listed according to the order in which they are called out in text, and appear in text as numbers within brackets. Duplications occur through all five volumes.

John B. Pate

ACKNOWLEDGMENTS

The authors wish to acknowledge the direct participation of the Research Division of the U.S. Army Tropic Test Center (USATTC). Commanding officers were Col. Pedro R. FlorCruz and Col. John Zakel Jr. Direct supervision and assistance for various parts of the research program were given by Drs. Leo Alpert and Guy N. Parmenter, consecutive Chiefs of the Research Division. The entire staff of the Research Division and many USATTC personnel assisted with various phases of the program. Michael A. Fradel, Project Officer for the Data Base Program, provided invaluable assistance with the meteorological and soil data and with the data-handling techniques.

Individuals listed as authors of this report series are those who sustained a major, continuing involvement in work leading to the results given in the respective volumes. We would also like to acknowledge the important contributions made by the following in many phases of the project: H. D. Axelrod, J. Flax, E. R. Frank, M. D. LaRue, A. L. Lazrus, R. A. Rasmussen, G. E. Sturdy, and A. F. Wartburg (all of NCAR); and H. Burke, B. B. Correa, R. Ehrman, R. J. Garner, G. Gauger, A. Gonzales, G. Llano, M. Mee, R. Midwood, R. Mueller, S. Polanco, E. L. Tyson, and V. Wong (all of the USATTC). Sandra Fuller and Paul Carlock (NCAR scientific programmers) and Roger Breeding (also of NCAR) wrote programs for and assisted with all phases of the data processing.

CONTENTS

FIGURES

I. INTRODUCTION

A. OBJECTIVES

The background and objectives of the U.S. Army Environmental Data Base for Regional Studies in the Humid Tropics (Data Base Program) have been described by the USATTC [1-6]. During early consultations with NCAR, it became clear that a cooperative effort by NCAR and the USATTC on chemical measurements made under the Data Base Program would enable NCAR to achieve parallel but distinct objectives of its own. NCAR's objectives were to: (1) measure existing concentrations of trace atmospheric constituents in the tropics; (2) determine characteristics of the chemical reactions occurring in the atmosphere of the humid tropics; and (3) characterize the sinks and sources of trace atmospheric constituents in the tropics.

B. CONTRACTUAL AGREEMENT

During 1965-66 the USATTC provided support for travel by NCAR personnel to the Canal Zone. During this preliminary period, methods were field tested and USATTC personnel were trained to make selected measurements on a continuing basis. These early studies provided data of such a nature [7] that a formal contract to provide support for travel and equipment was requested from the Army Research Office, Durham, N. C., so that a more intensive and systematic investigation could be made.

C. EXPERIMENTAL DESIGN FOR CHEMICAL MEASUREMENTS

Most of the concurrent meteorological, soil, chemical, and biological measurements were made at the Albrook Forest site (see Sect. II of this volume). One-hour average concentrations of several gases were measured by USATTC personnel four times a day, twice a week, from the 2-m (under forest canopy) and 46-m (above the forest canopy) levels of a tower erected at that site. Aliphatic aldehyde (RCHO, R=Hydrogen or alkyl group) concentrations were measured from May 1966 to November 1968, and nitrogen dioxide (NO_2) concentrations were measured in January 1969. Ammonia (NH_3) concentrations were measured from February 1967 through January 1969. The total numbers of these measurements at the Albrook Forest site were: ammonia, 1,126; nitrogen dioxide, 1,651; and aliphatic aldehydes, 1,546.

At selected times, NCAR personnel traveled to the Canal Zone and, working with USATTC personnel, made additional measurements. The numbers of samples measured are given in Table 1. These were collected at 25 special sites as well as at the Albrook Forest and Chiva Chiva data base sites. The special sites were selected to provide data for comparison with those collected to provide data for comparison with those collected at the data base sites. A limited number of samples were also collected from airplanes, helicopters, and a ship. Some samples (or portions of samples) were reserved for future analyses. Table 1 shows the present storage locations of collected samples.

Table 1

NUMBERS AND TYPES OF CHEMICAL MEASUREMENTS

Gases	Number of Samples	Sample Repository
Ammonia (NH_3)	1,568	-----
Nitrous oxide (N_2O)	116	-----
Nitric oxide (NO)	518	-----
Nitrogen dioxide (NO_2)	2,055	-----
Sulfur dioxide (SO_2)	518	-----
Aliphatic aldehydes (RCHO)	1,758	-----
Hydrocarbons (5-25 species measured per sample)	568	-----
Particles		
Impactor - formaldehyde content	265	-----
Impactor - classified by type	183	NCAR
Filter - mass loading	32	NCAR
Filter - chloride size distribution	253	NCAR
Filter - sulfate size distribution	215	NCAR
Filter - optical density	10,400	USATTC
Filter - for future analysis	237	NCAR

D. PRESENTATION AND EVALUATION OF DATA

The Data Base Program was designed to provide a data bank of information and analyses derived from observations of selected physical and biological characteristics at representative sites in the tropics. Although a limited amount of evaluation was

done concurrently with data gathering, we expect that these data will be used as source material for evaluation over a period of many years. Details of data coding, format, and storage are given in Vol. V.

The meteorological and soil data consist of an extensive, relatively homogeneous series of measurements. Summary reports of these data have been issued [8, 9] and a limited amount of evaluation has been published [1-6]. The entire file of meteorological and soil data is incorporated in and available from the primary repository of the environmental data bank at the U. S Army Test and Evaluation Command Headquarters in Aberdeen, Maryland.

The types and durations of the chemical and biological measurements are relatively heterogeneous. The chemical data are described in [7, 10-23]; methodology of atmospheric sampling and analysis developed in part in Panama are discussed in [24-29]. Exemplary data from the study are used in [30-38], and biological and biological-chemical data are presented in [39-46]. In addition, discussions of limited studies were published as sections or brief papers in the USATTC semiannual reports [47-58].

Since the chemical and biological data are not excessively bulky, they are presented in full in Volumes II, III, and IV of this report. They are also included on magnetic tape in the data bank.

II. SITE DESCRIPTIONS

The sites used for chemical and biological sampling are listed in Table 2; site locations are shown in Figs. 1-3. The cruise track of the S. S. Advance II (Fig. 3) designates the sea site; most of the ground sites are depicted in Figs. 4-52; and, the aerial site locations are shown in Fig. 53.

Table 2

SITE LISTINGS (CHEMICAL)

Site Designation	Site Name	Site Designation	Site Name
NCAR Special Sites		**Data Base Sites**	
N1	Ft. Sherman-Bunker	D1	Albrook Forest
N2	Ft. Sherman-Beach	D2	Chiva Chiva
N3	Rio Piedras		
N4	Skunk Hollow		
N5	Ft. Sherman-Swamp		
N6	Coco Solo Swamp		
N7	Chagres River	**Aerial Sites**	
N8	Contadora Island		
N11	Rio Hato-Savannah	A1	Brujas Point
N12	Madden Ridge Road	A2	Chepillo Island
N13	Rio Hato-Beach	A3	del Rey Island
N14	Coco Solo	A4	Panama City
N15	Pidiaque	A5	Madden Dam
N16	Albrook-Road End	A6	Pidiaque
N17	Rio Mar	A7	Soskatupo
N18	Barbados-East Point	A19	Barbados
N19	Barbados-North Point		
N20	Soskatupo		
N21	Agua Salud		
N22	Galeta Point	**Shipboard**	
N23	Madden Preserve		
N24	Miraflores Laboratory		
N26	Soufriere, St. Lucia	S25	S. S. Advance II

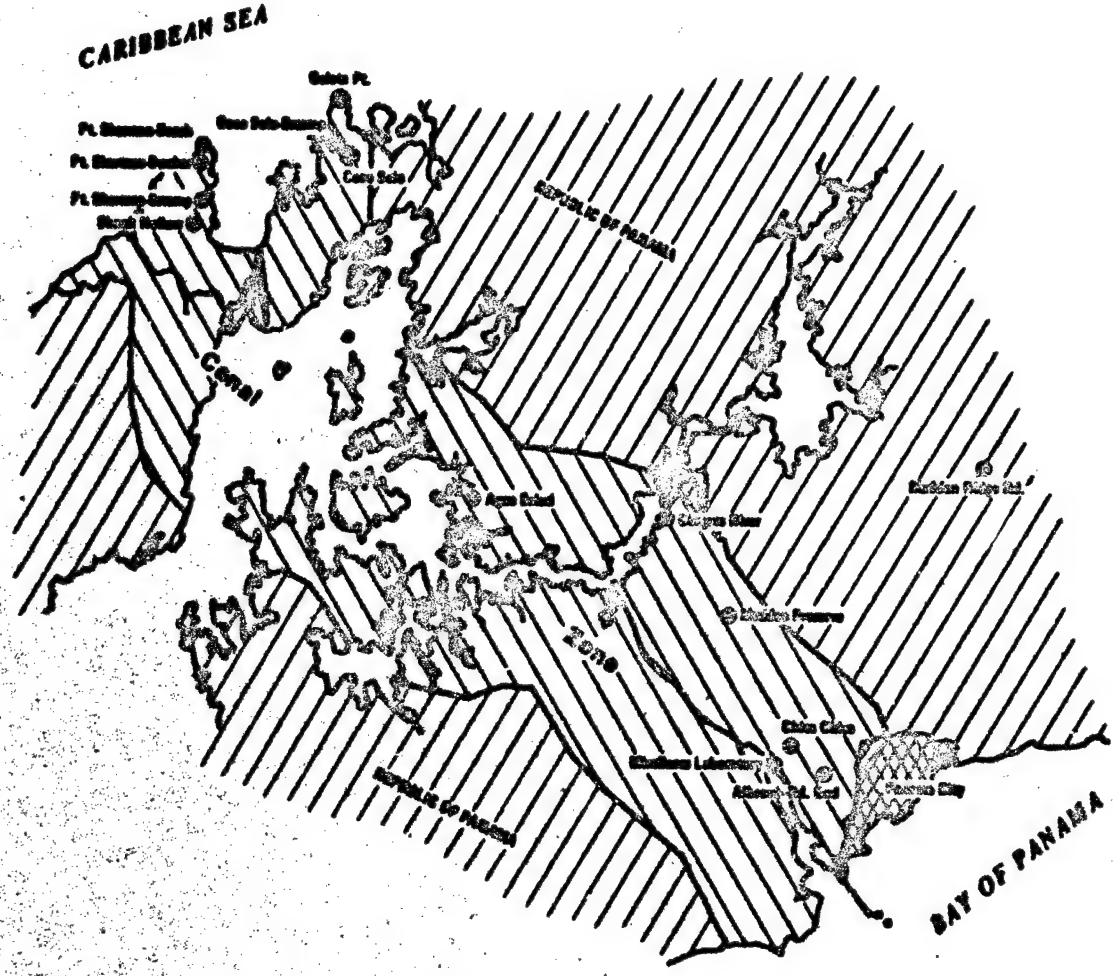


Fig. 1 Chemical sampling sites in the Panama Canal Zone.

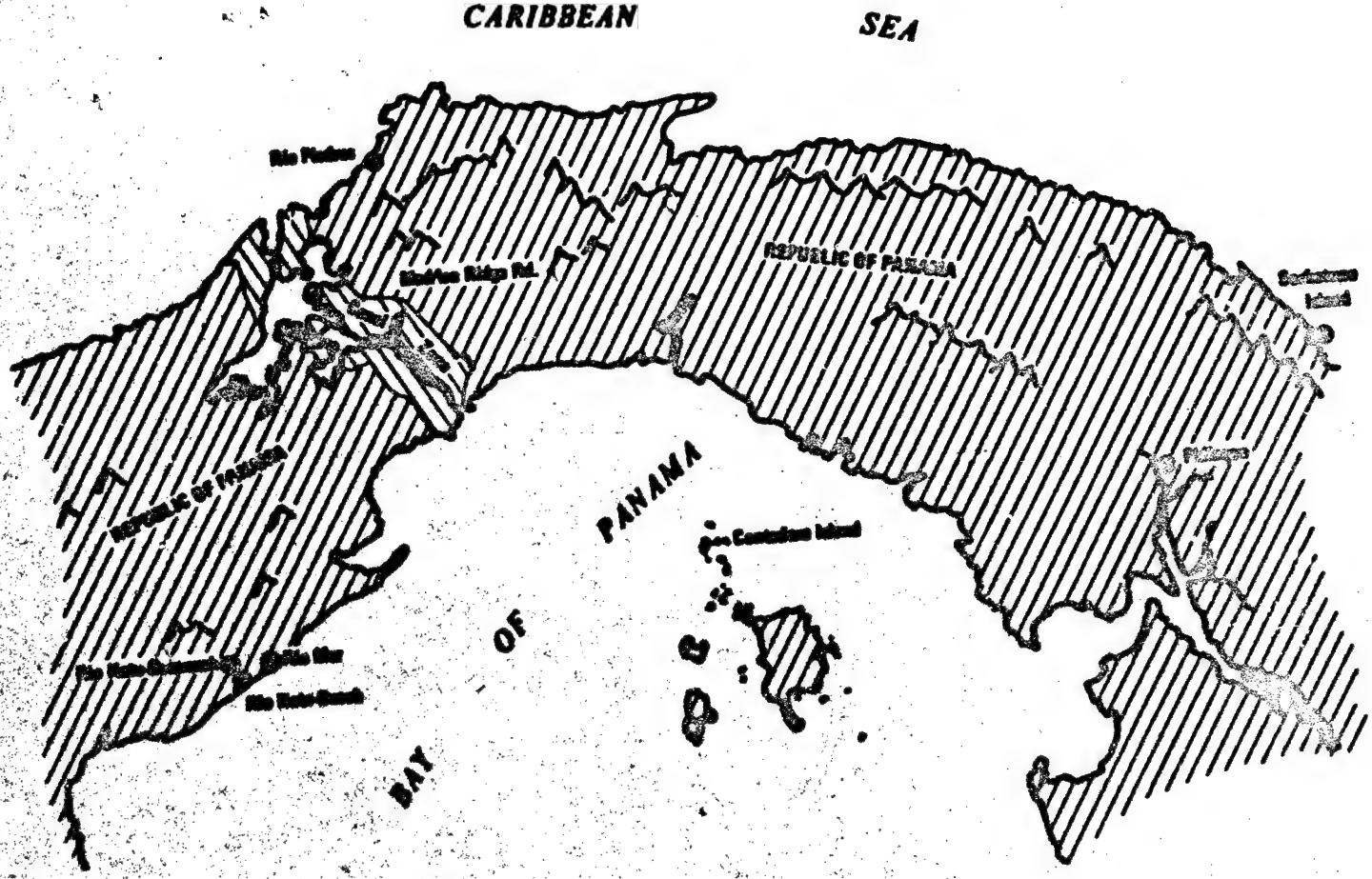


Fig. 2 Chemical sampling sites in the Republic of Panama .

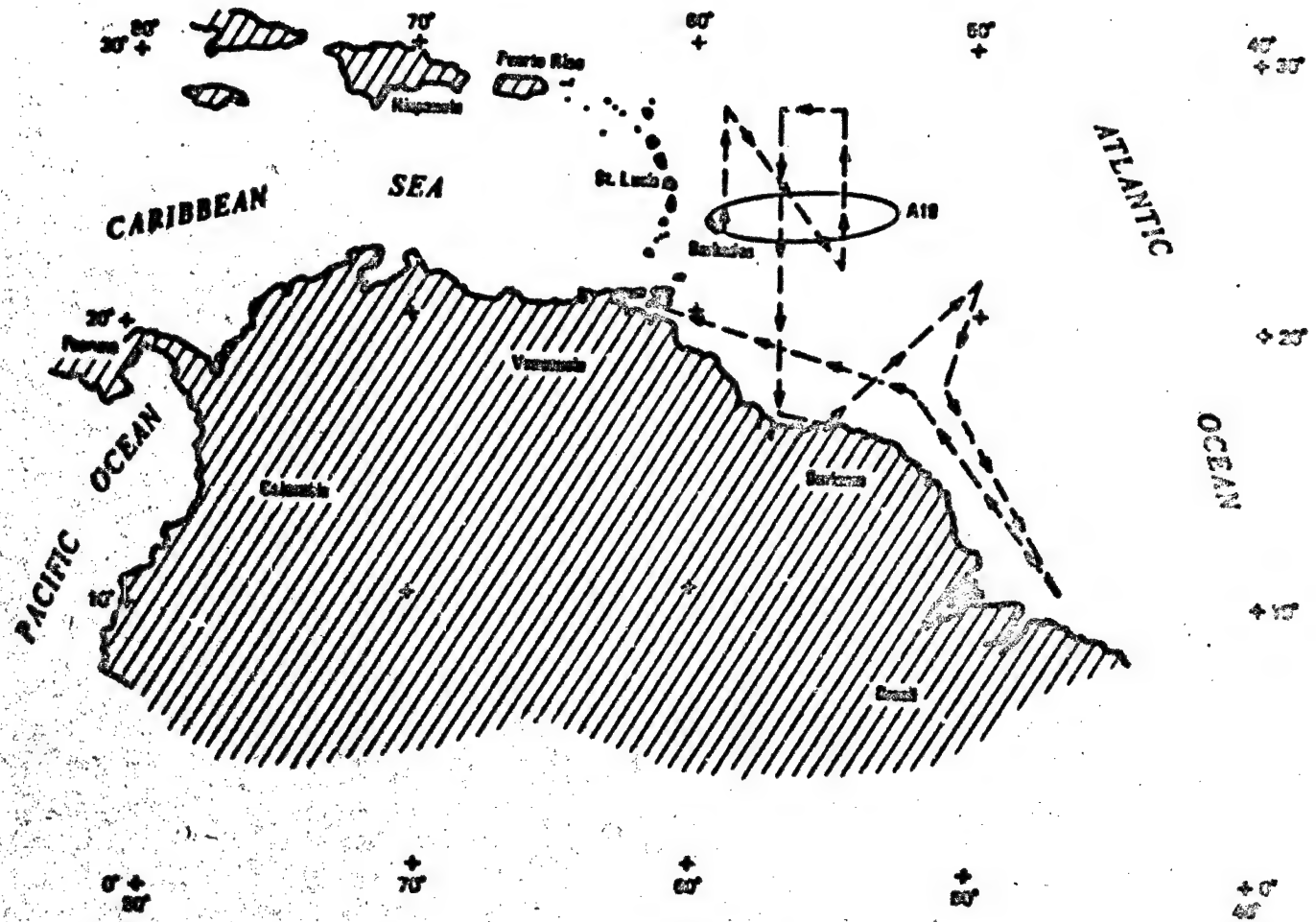


Fig. 3 Chemical sampling sites in the Caribbean Sea; path of arrows is the cruise track of the S. S. Advance II.

A. Data Base Sites

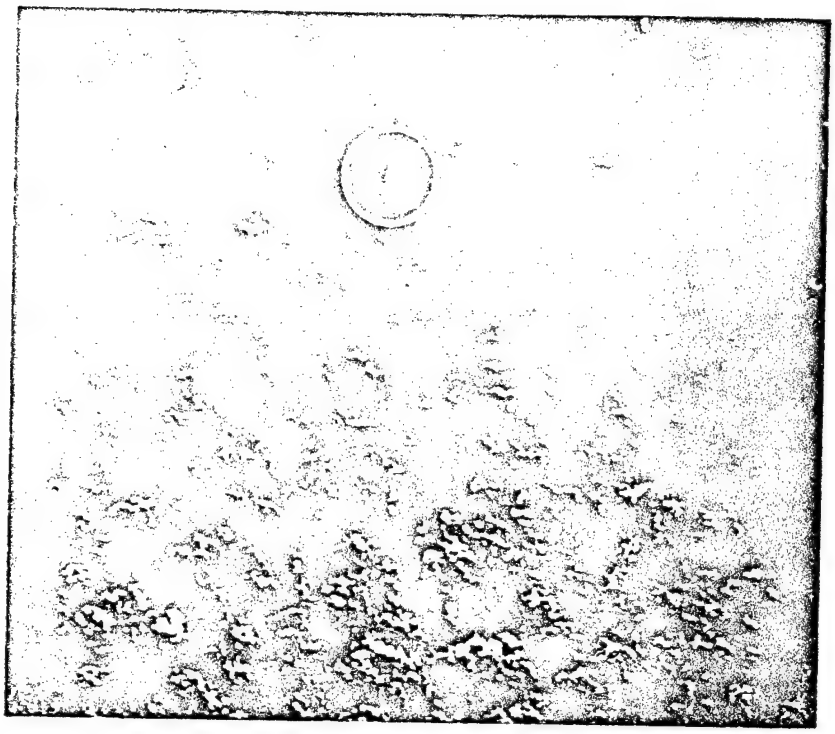
Albrook Forest (Data Base Site #1). The Albrook Forest site is in the Panama Canal Zone at lat. 9°0'53" and long. 79°32'26"; ground elevation ranges from 30 to 33 m above sea level. The site has a 4% slope to the southeast and is in a region of rounded hills whose heights reach 130 m. The nearest hills are 400 m to the east; others are 600 m to the northwest.

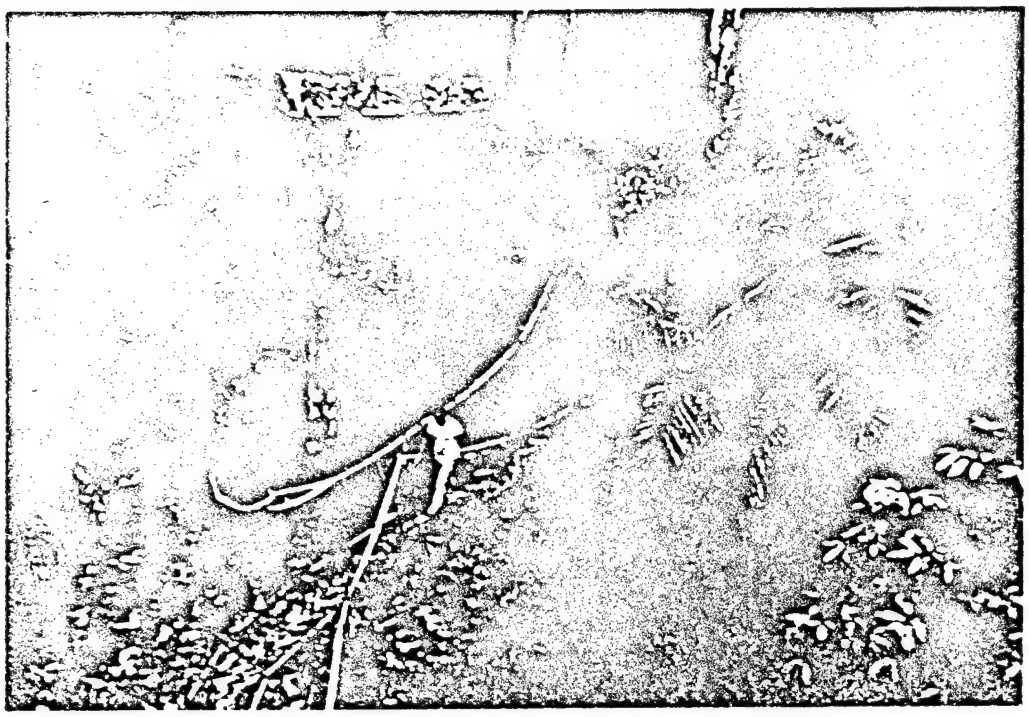
A 46-m high walk-up tower was built at the center of the site. Figure 4 is an aerial view of the forest showing the portion of the tower that extends above the canopy. Figure 5 is a view from the ground of chemical sampling in progress at the 46-m level of the tower.

The site is on a low, erosional terrace where the soil is a residual clay oxisol, rich in organic matter, with a light-textured surface. The parent material is an agglomeratic tuff. Further site details and descriptions of selected soil and meteorological measurements can be found in [1-3] and [6].

The vegetation consists of many species of trees, shrubs, and vines, many of which are deciduous. The top of the tree canopy was 26-28 m above the surface at the beginning of the study; by the end of the study it had grown appreciably. The forest extends for several kilometers in all directions except to the east where it has been cleared. The undercanopy vegetation at the tower base is shown in Fig. 6.

Detailed studies on the vegetation characteristics at the site have been reported [47, 55-58].





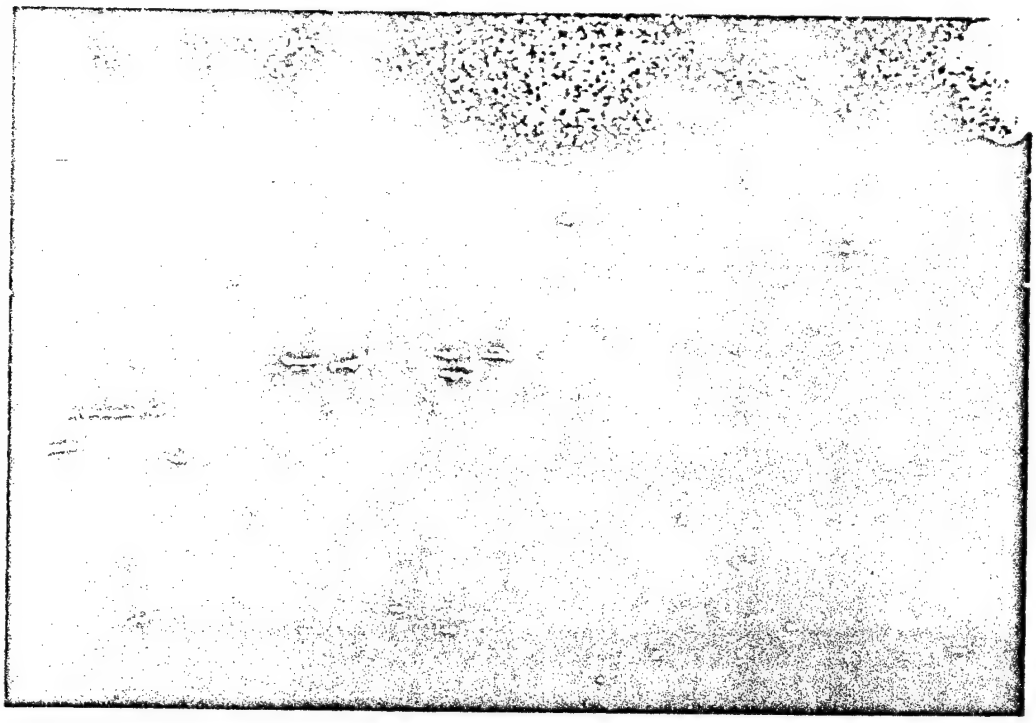


Fig. 7 Data Base Site #2 (Chiva Chiva) and surroundings.

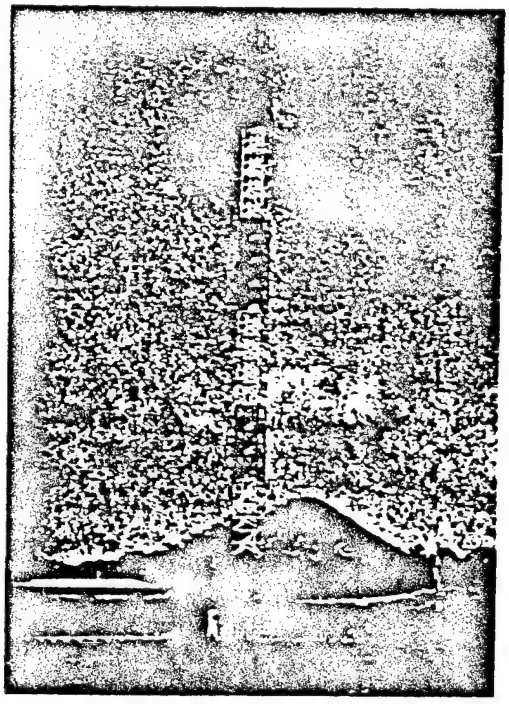


Fig. 8 Tower at Chiva Chiva site.

B. Special Sites

Ft. Sherman-Bunker (Special Site #1). The Ft. Sherman-Bunker site is in the Panama Canal Zone at lat. 9°22'0" and long. 79°56'56". A bunker equipped for use as a meteorological station occupies the top of a small knoll (Fig. 9). The station is operated by a U.S. Army meteorological team. Some samples were collected on the bunker roof; others were collected at the top of the knoll directly behind the bunker (Fig. 10).

The site, at an elevation of 5 m, is approximately 250 m south of the mouth of the Shelter Cove which opens into Limon Bay immediately behind a breakwater. Shelter Cove lies to the northeast between the bunker and the seashore (Special Site #2).

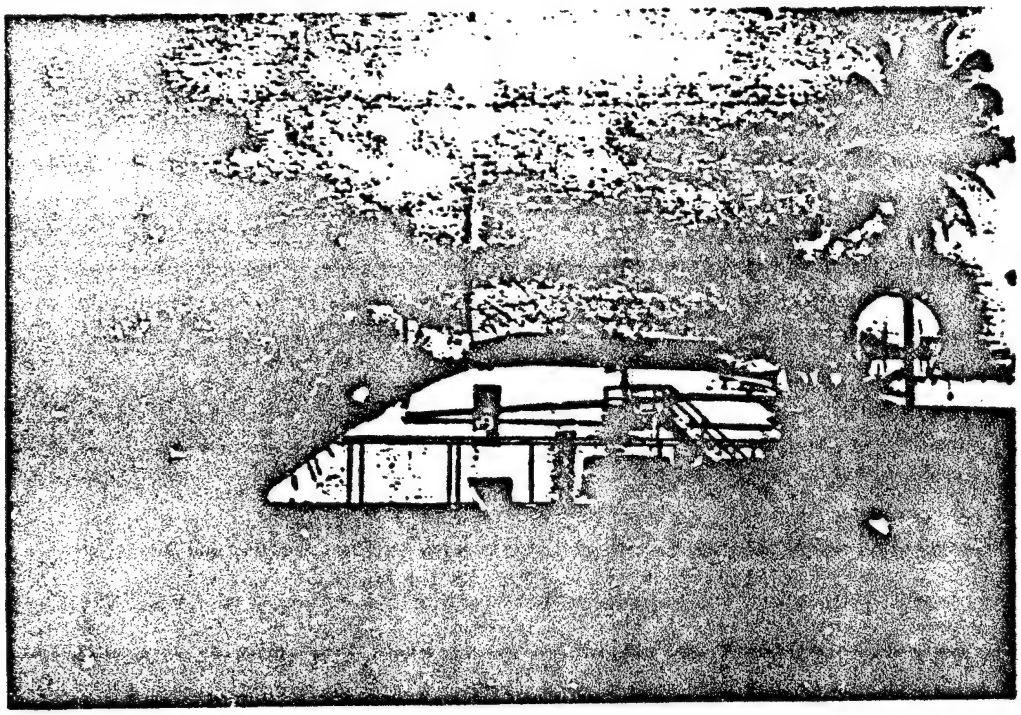


Fig. 9 Meteorological station, Special Site #1 (Ft. Sherman-Bunker).

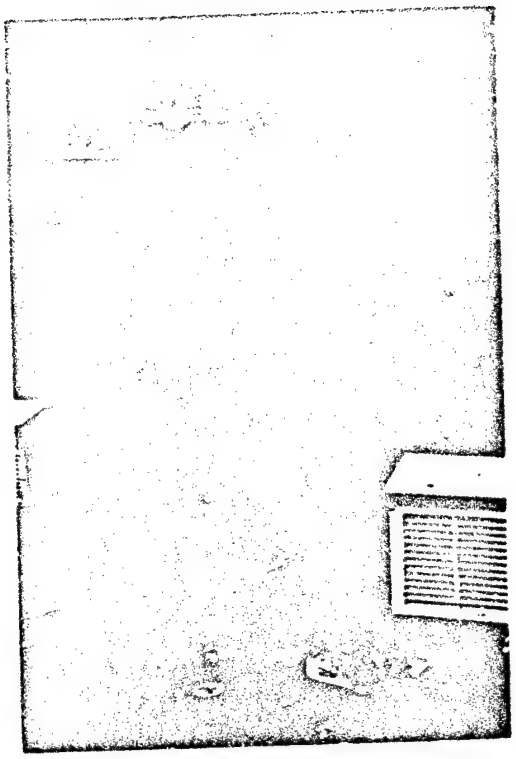


Fig. 10 View toward Caribbean Sea from Ft. Sherman-Bunker site.

Ft. Sherman-Beach (Special Site #2). The Ft. Sherman-Beach site is in the Panama Canal Zone at lat. 9°22'10" and long. 79°57'9". A few special samples were collected at this site to assess the possible effect of ocean-bottom exposure at low tide on the Ft. Sherman-Bunker site (Special Site #1). Elevation at this site is 0.5 m above sea level.

The sampling site was on the beach at the edge of a small, shallow bay (Figs. 11 and 12). The bottom of the bay, an extension of the outlying coral reef, is covered with a thin layer of coral sand mud and is almost totally exposed during low tide.

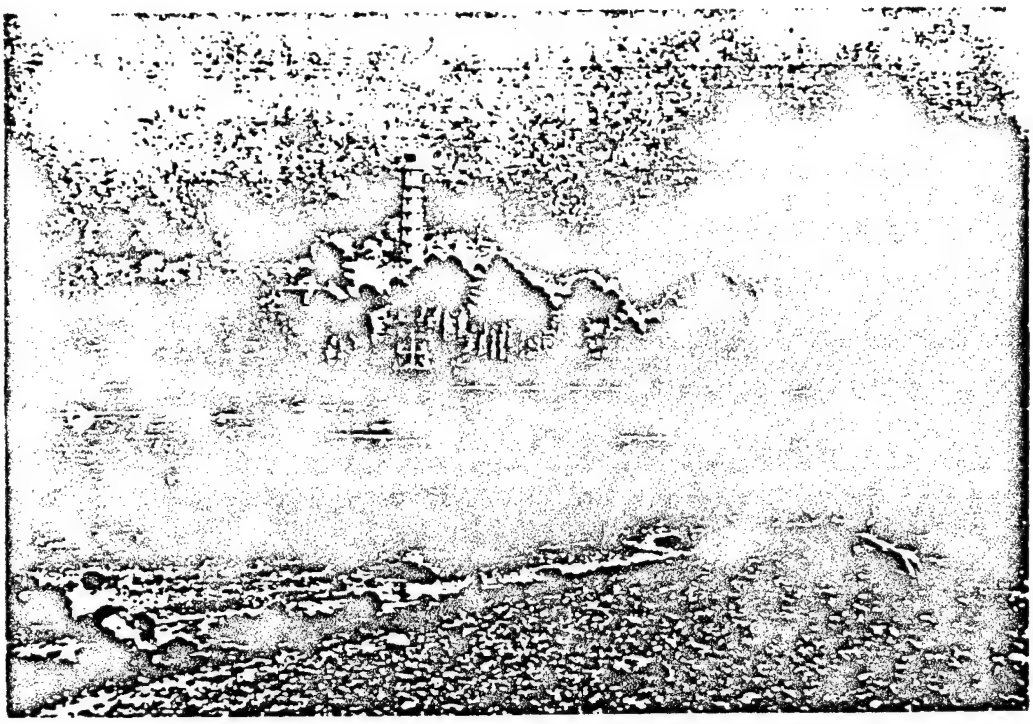


Fig. 11 Special Site #2 (Ft. Sherman-Beach).

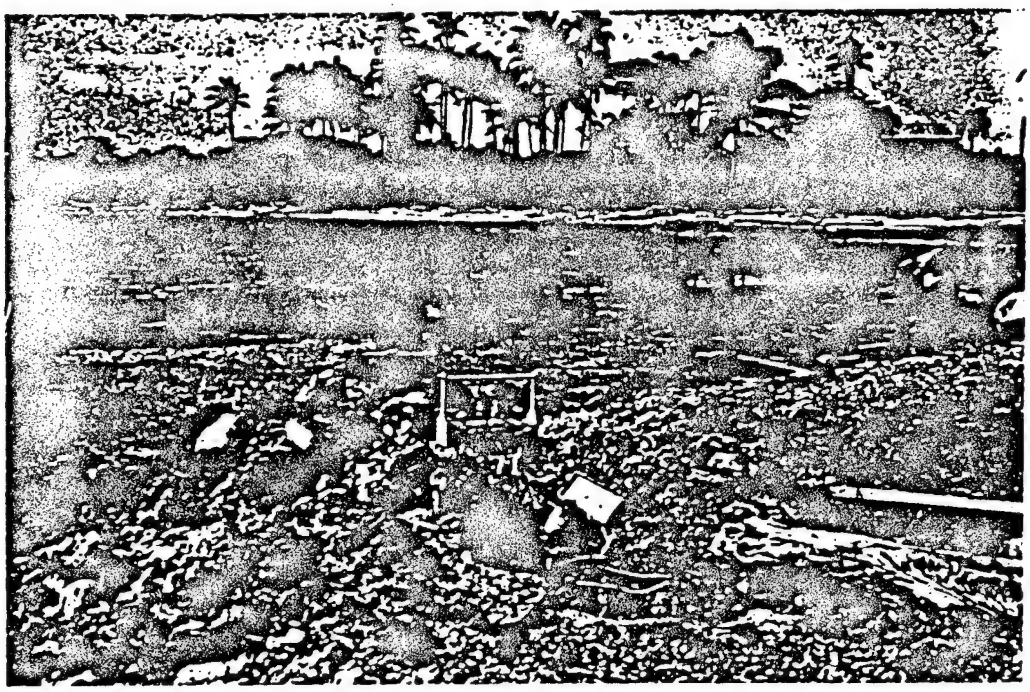


Fig. 12 Chemical sampling at Ft. Sherman-Beach site.

Rio Piedras (Special Site #3). The Rio Piedras site is in the Republic of Panama at lat. 9°27'10" and long. 79°44'32". The sampling point was on the beach of Punta Portete about 200 m west of the mouth of Rio Piedras. Ground level is 1 m above sea level.

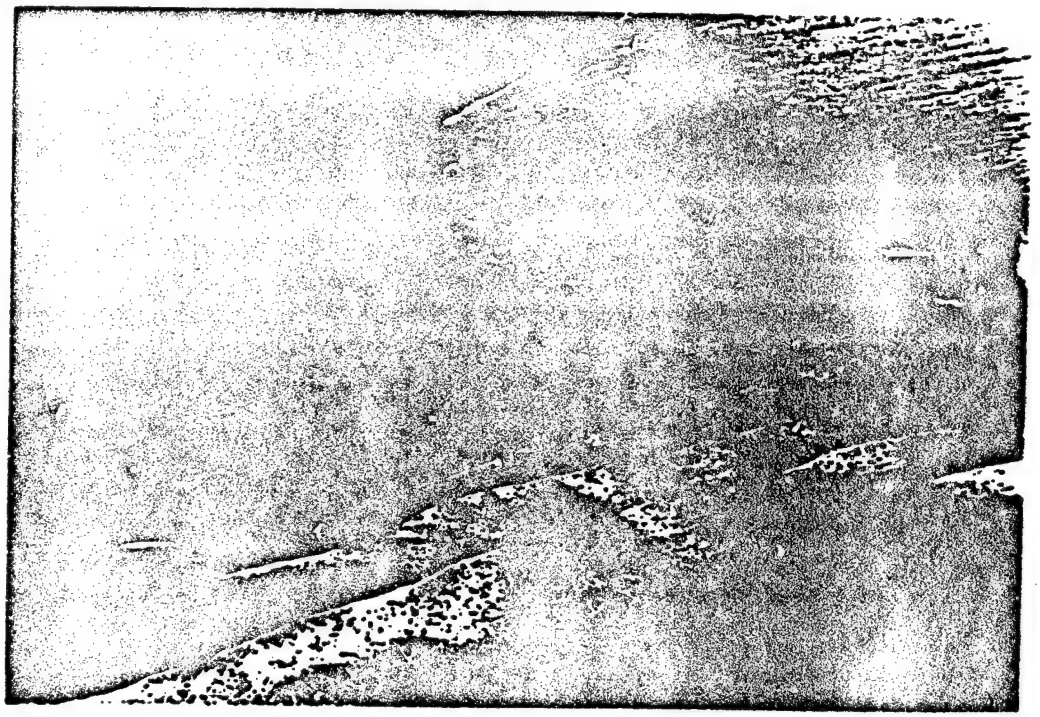


Fig. 13 Special Site #3 (Rio Piedras), Punta Portete.

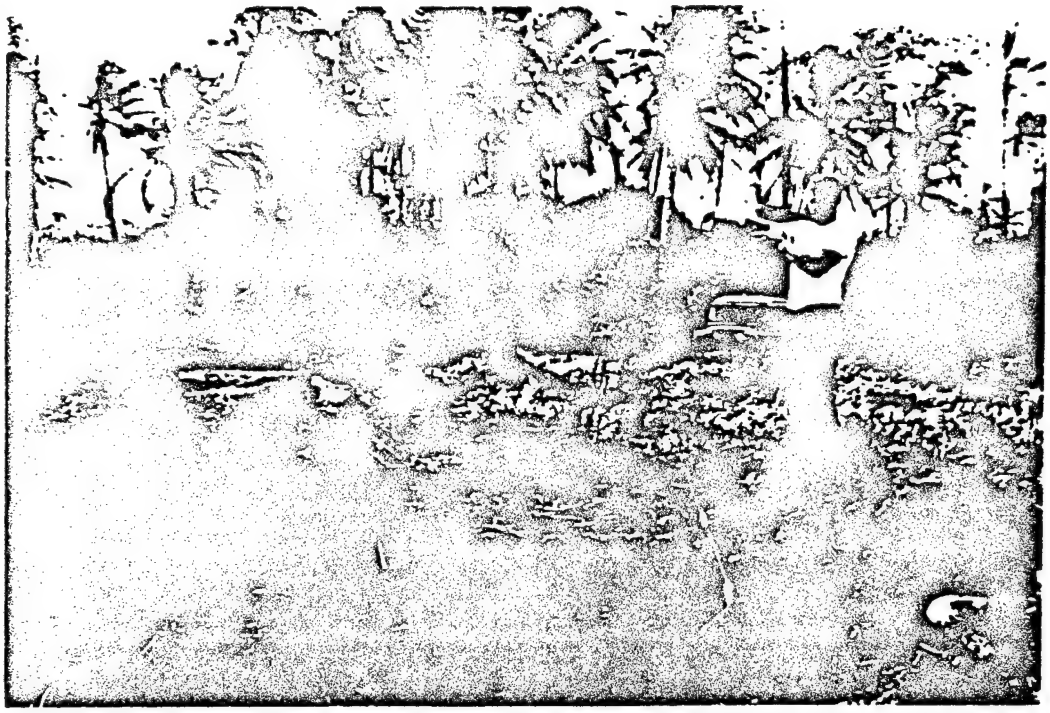


Fig. 14 Terrain at the Rio Piedras site.

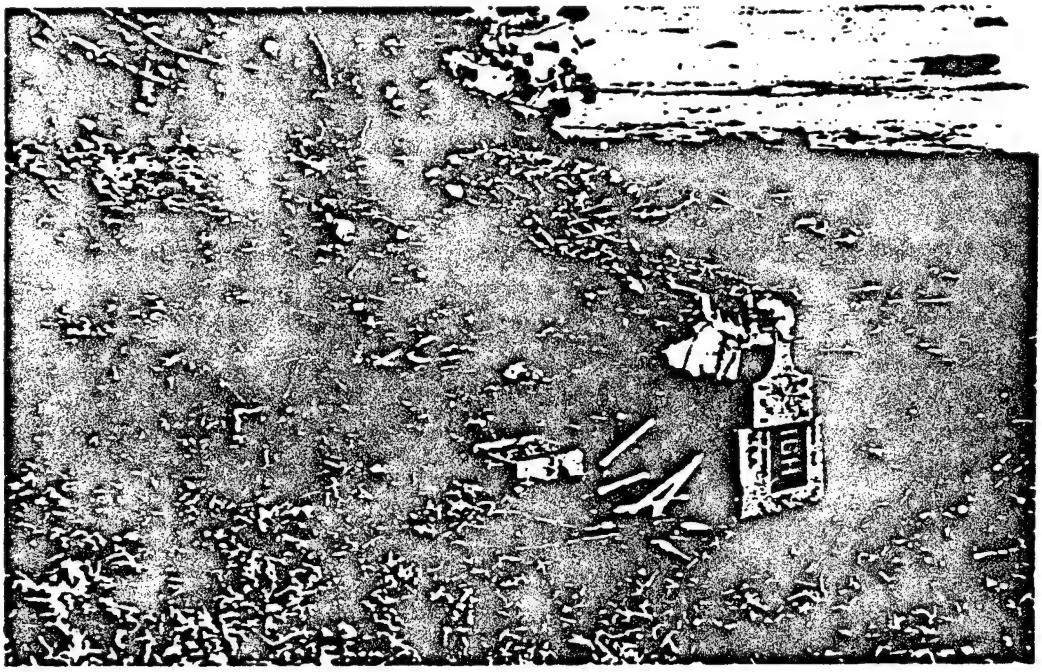


Fig. 15 View toward the Caribbean Sea from the Rio Piedras site.

Skunk Hollow (Special Site #4). The Skunk Hollow site is in the Panama Canal Zone at lat. 9°19'40" and long. 79°57'16". A few special samples were collected at this site, which has a higher average annual rainfall (330 cm) and a more even seasonal distribution of rain than Albrook Forest, so that the dry season is much less pronounced.

Sampling was carried out on the forest floor. The forest has a somewhat higher canopy and less understory vegetation (Fig. 16) than does Albrook. Elevation is about 25 m.

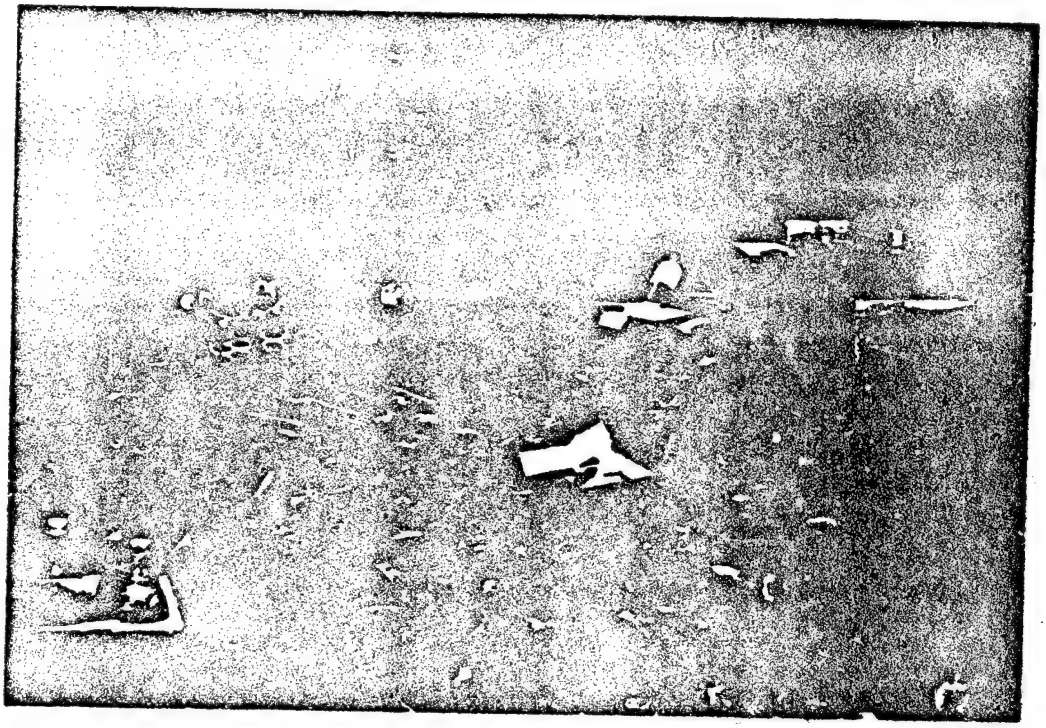


Fig. 16 Special Site #4 (Skunk Hollow).

Ft. Sherman-Swamp (Special Site #5). The Ft. Sherman-Swamp site (not pictured) is in the Panama Canal Zone at lat. 9°20'35" and long. 79°57'7". A few selected samples were collected several meters from the road in the mangrove swamp bordering Limon Bay. Ground level is 0.5 m. The main vegetation is second-growth red mangrove with heights up to 7-8 m. Stems are small (to 15 cm D.B.H.--stem diameter at breast height) and closely spaced (mean N.N.D.--net nearest distance--2 m). Prop roots are extensive and form a thick mass. Vegetation beneath the canopy consists of scattered clumps of giant fern. Salt water floods the area during extreme tides.

Coco Solo Swamp (Special Site #6). The Coco Solo Swamp site is in the Panama Canal Zone at lat. 9°22'48" and long. 79°52'44". The sampling site was about 15 m from the road in the mangrove swamp border on an almost landlocked inlet of the Caribbean (Fig. 17).

Vegetative cover is nearly mature white mangrove to a canopy height of 20 m. Stems reach 28 cm D.B.H., but average 18-20 cm. Mean N.N.D. is approximately 3.5 m. Ground cover is restricted to the fern Acrostrichum. No prop roots are present, though pneumatophores to heights of 20 cm are numerous. Salt water floods the area during extreme tides.

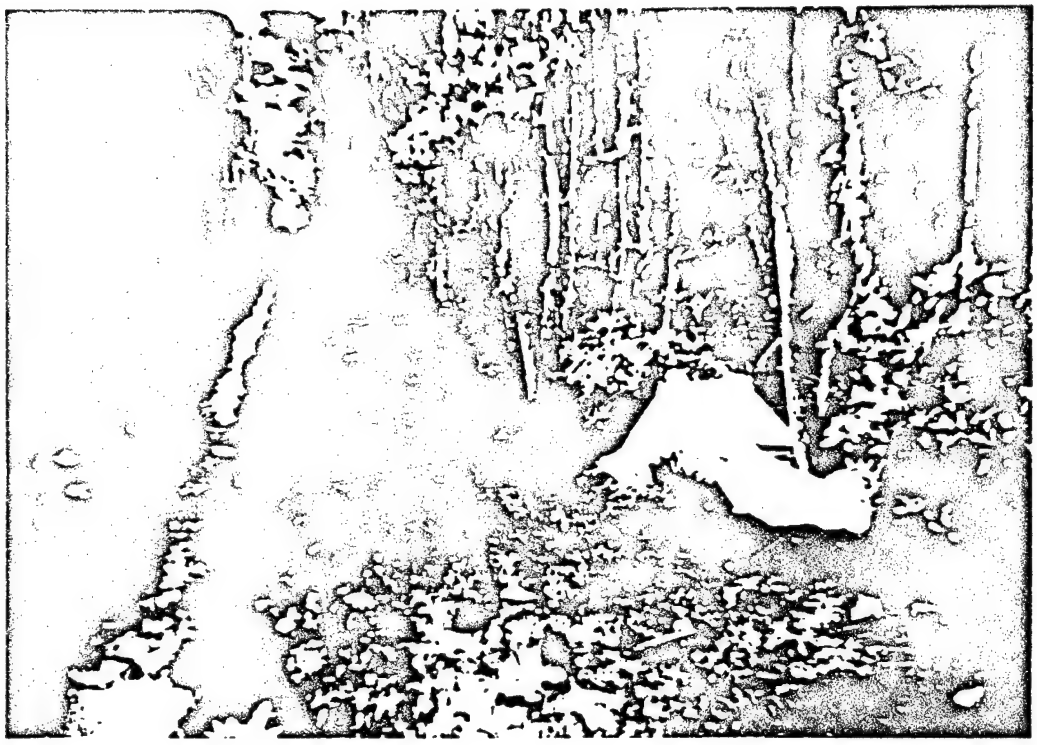


Fig. 17 Sampling at Special Site #6 (Coco Solo Swamp).

Chagres River (Special Site #7). The Chagres River site is in the Panama Canal Zone at lat. 9°10'6" and long. 79°39'37", on a vegetation-blocked inlet of the Chagres River (Fig. 18). Samples were collected from the end of the dock shown in Fig. 19.

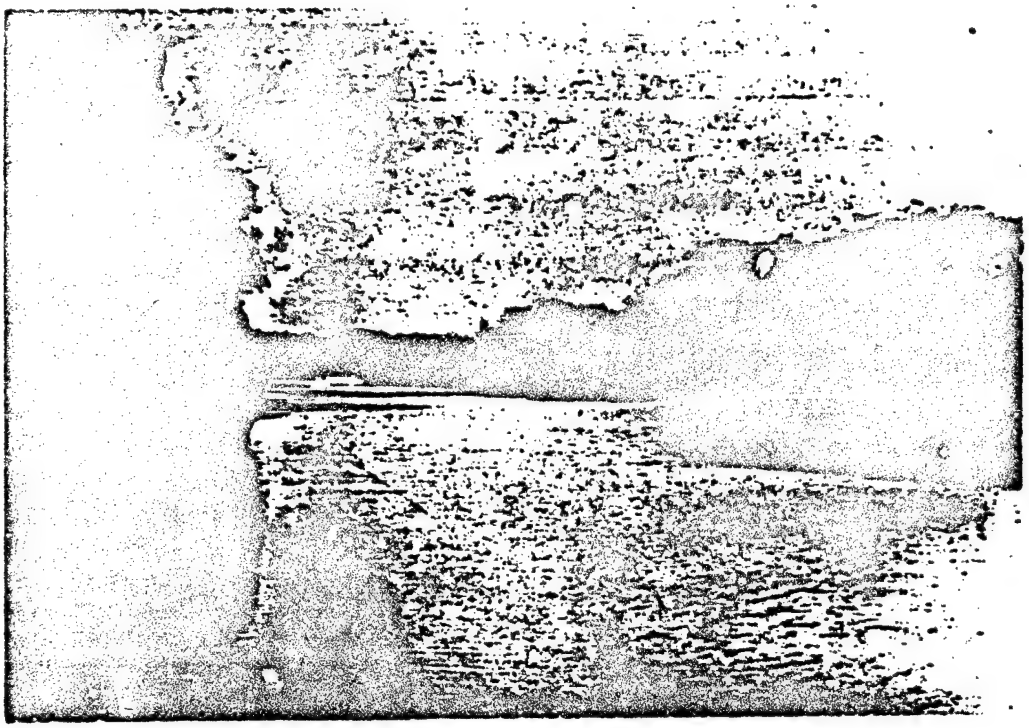


Fig. 18 Special Site #7 (Chagres River).

Fig. 19 Sampling point at Chagres River site.

Contadora Island (Special Site #8). Contadora Island is one of the Pearl Islands in the Bay of Panama on the Pacific side of the Isthmus. The site is at lat. 8°38'11" and long. 79°2'10" on the tip of a rocky point (Figs. 20 and 21) at the north end of the island.

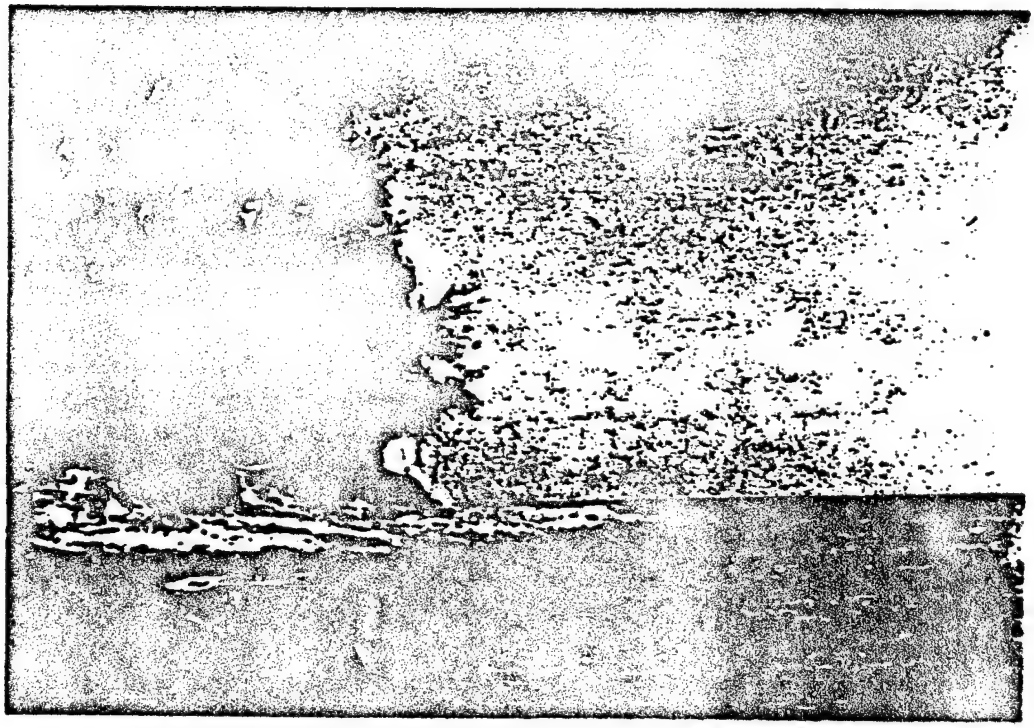


Fig. 20 Special Site #8 (Contadora Island).

Fig. 21 Sampling at Contadora Island site.

Rio Hato-Savannah (Special Site #11). The Rio Hato-Savannah site is in the Republic of Panama at lat. 8°24'31" and long. 80°8'18". The area is tropical grassland (savannah) with scattered trees on the Pacific coastal plains of Panama (Fig. 22). The elevation of the sampling site (Fig. 23) is 30 m. The grasses are thick and green during the rainy season, but turn brown and are sometimes burned or cut during the dry season.

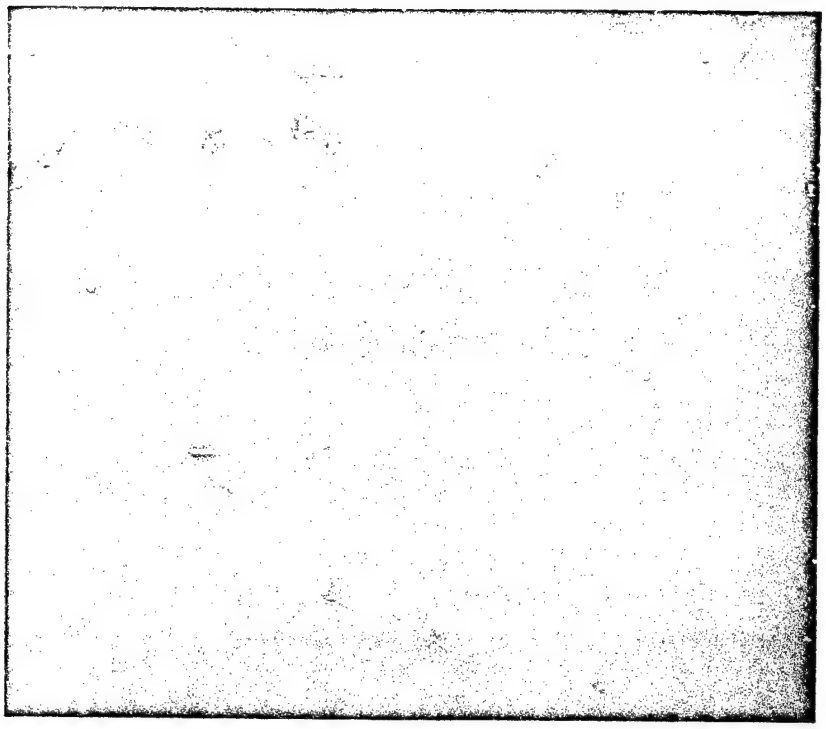


Fig. 22 Aerial view of tropical savannah, Rio Hato area.

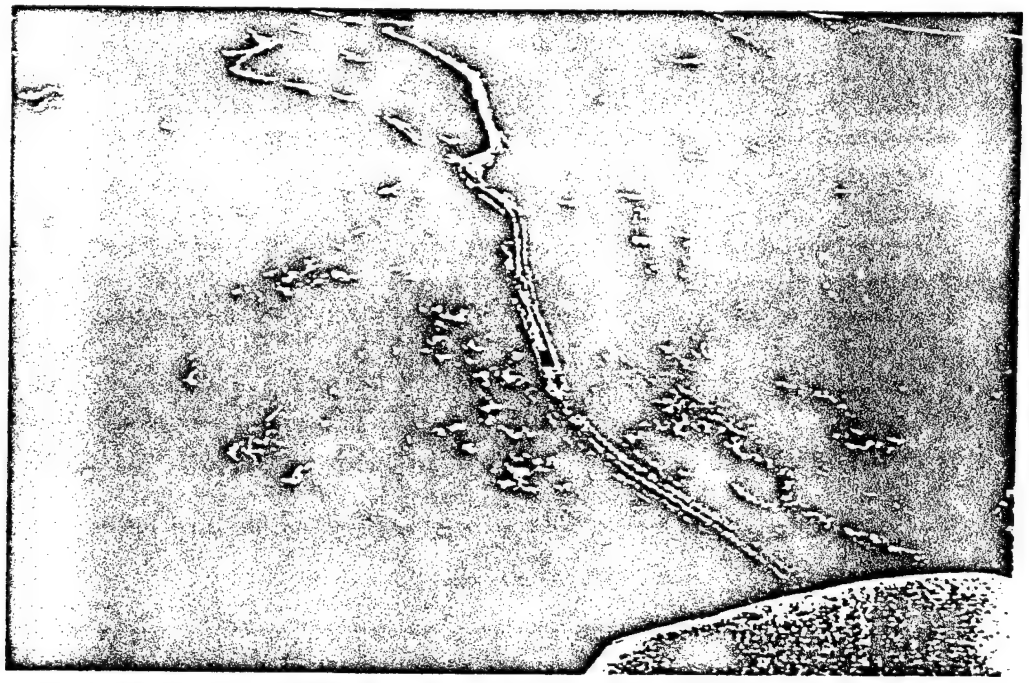


Fig. 23 Special Site #11 (Rio Hato-Savannah).

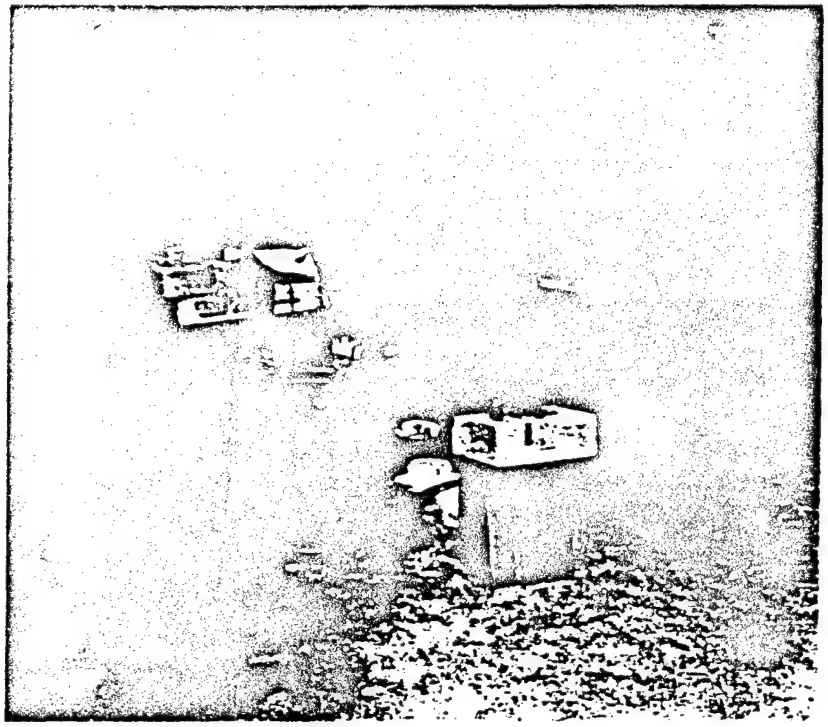


Fig. 24 Sampling at Rio Hato-Savannah site.

Madden Ridge Road (Special Site #12). The Madden Ridge Road site is in the Republic of Panama at lat. 9°14'24" and long. 79°21'39", adjacent to the road which follows the continental divide along the ridge edging the Madden Basin drainage system (Fig. 25). The elevation is estimated at 800 m. The general area is a lower cloud forest zone. The sampling point was located at the edge of an old burn (Fig. 26).

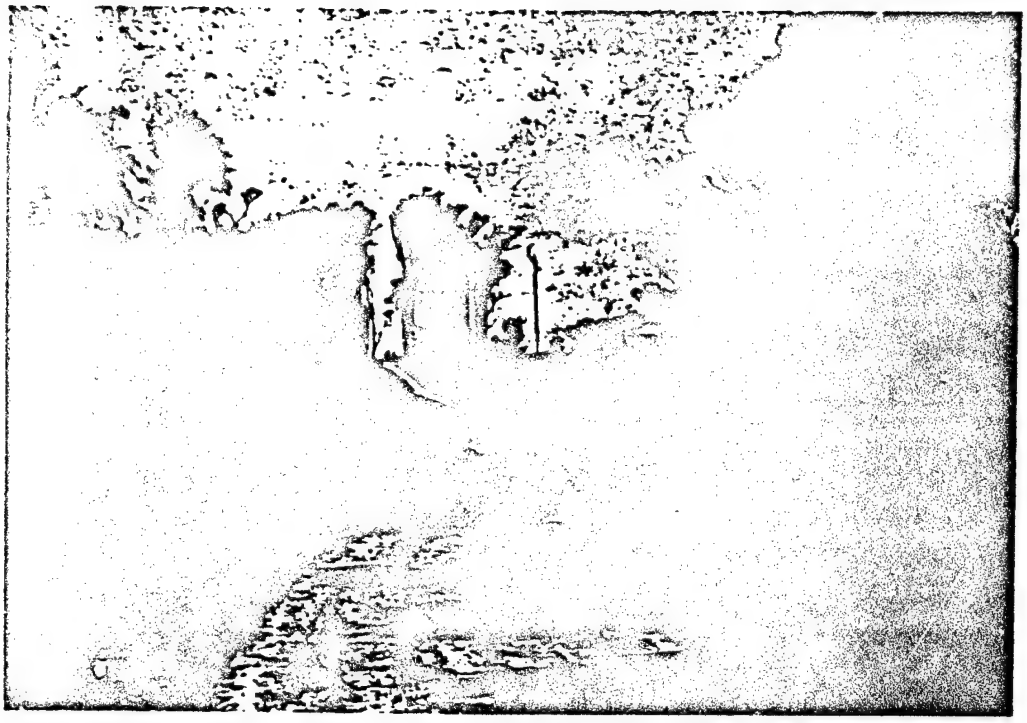


Fig. 25 Madden Ridge Road.

Fig. 26 Special Site #12 (Madden Ridge Road).

Rio Hato-Beach (Special Site #13). The Rio Hato-Beach site is in the Republic of Panama at lat. 8°24'30" and long. 80°6'22". The savannah in this area (see also Special Site #11) extends to a bluff on the edge of a sandy beach that borders the Bay of Panama (Fig. 27). The sampling site is a grassy plot on the edge of the bluff above the beach and is fringed with low trees and shrubs (Fig. 28). The site is on the border of the Rio Hato Military Reservation (Fig. 29); elevation at the site is about 15 m.

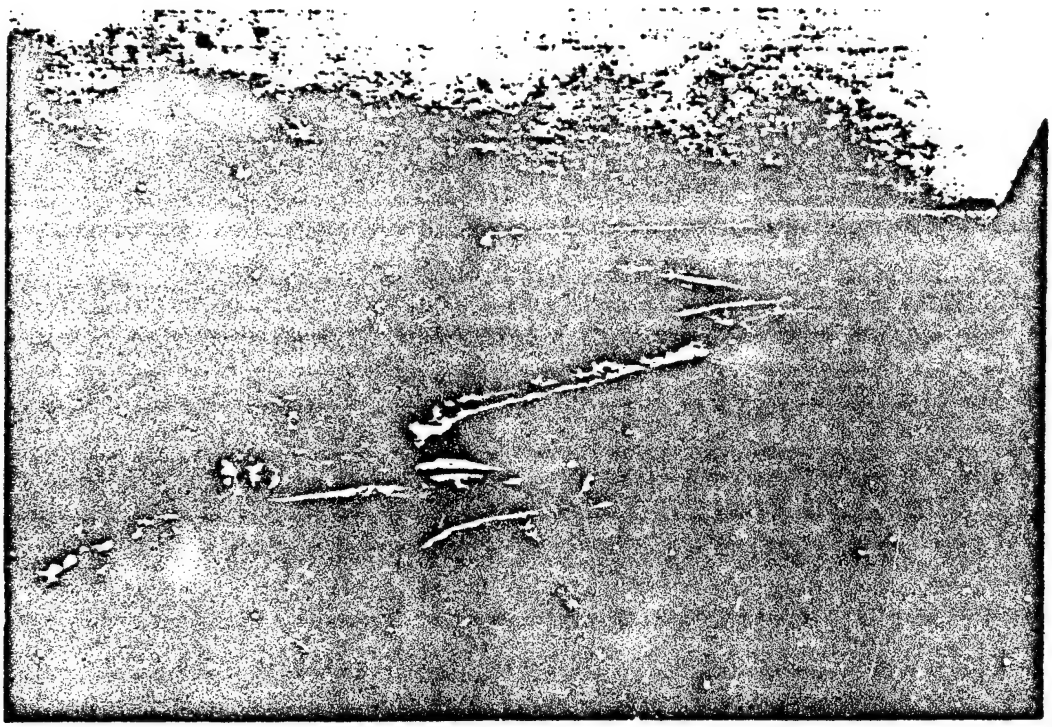


Fig. 27 Sand beaches between savannah and Bay of Panama (Rio Hato area).

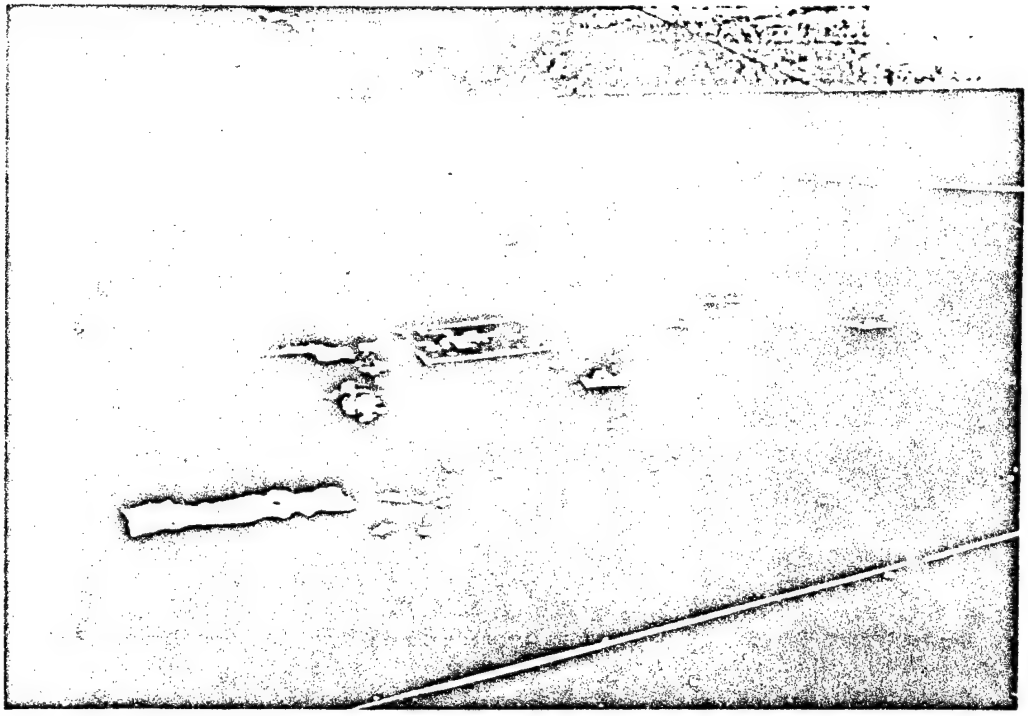


Fig. 28 Special Site #13 (Rio Hato-Beach).

Fig. 29 Camp at Rio Hato-Beach site.

Coco Solo (Special Site #14). The Coco Solo site is in the Panama Canal Zone at lat. 9°22'57" and long. 79°51'43". Elevation is 12 m. The sampling point is a 2-m wide concrete strip leading into the forest (Fig. 30). The large annual rainfall (330 cm), and subsequently less-pronounced dry season, produces a tropical evergreen forest consisting of a luxuriant undergrowth in the absence of a high, dense canopy.

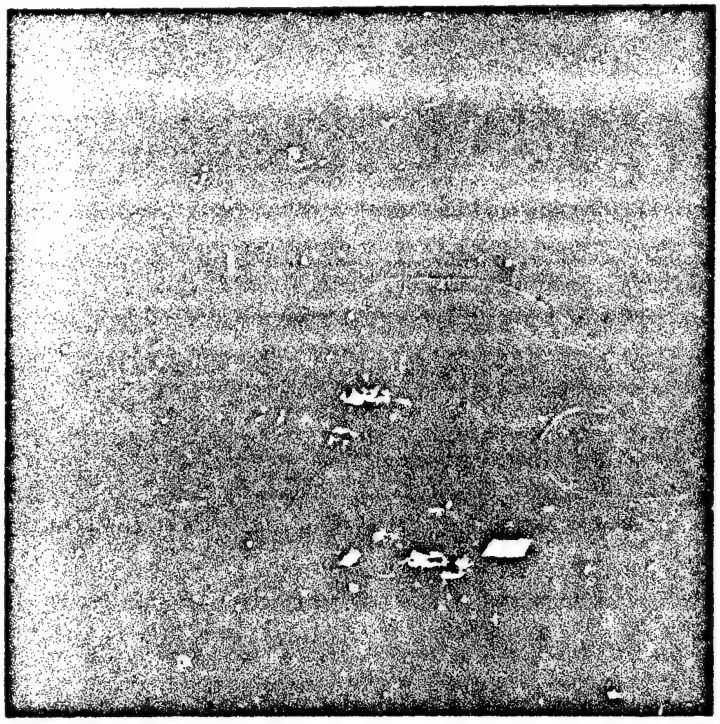


Fig. 30 Special Site #14 (Coco Solo).

Pidiaque (Special Site #15). The Pidiaque site is in the Republic of Panama at lat. 8°31'15" and long. 78°8'7", on a ridge overlooking the Sabana River in Darien. Elevation of the site is 240 m; access was by helicopter. The site was used as a meterological station by the Atlantic-Pacific Interoceanic Canal Study Commission during its study of Route 17 for a sea-level canal [9].

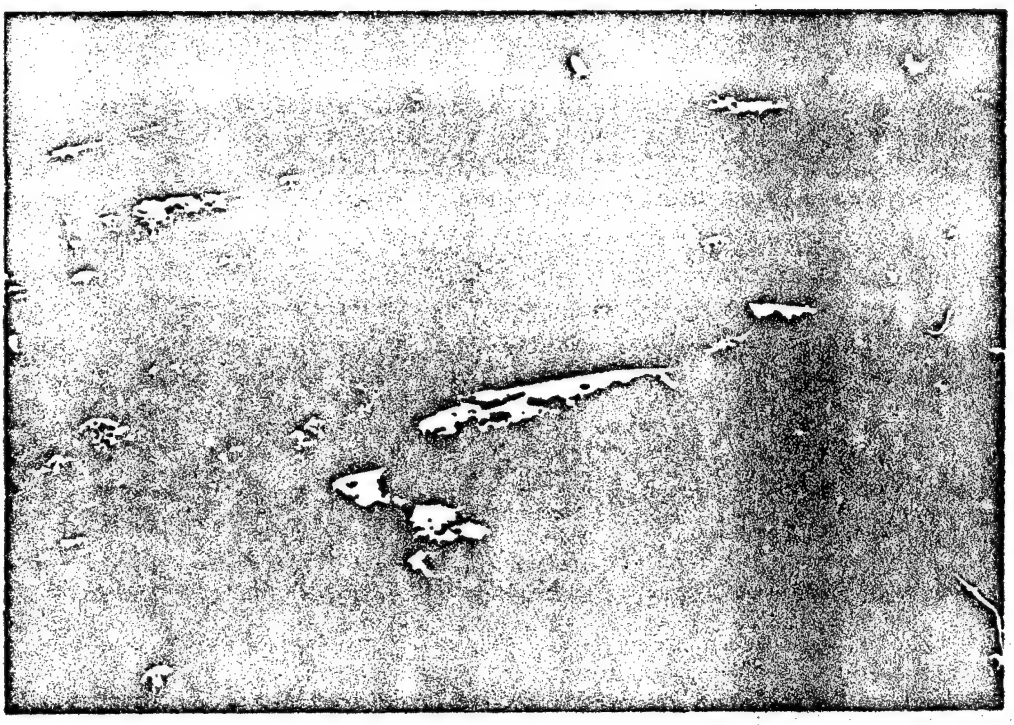


Fig. 31 Special Site #15 (Pidiaque).

Fig. 32 Terrain toward northeast from Pidiaque site.

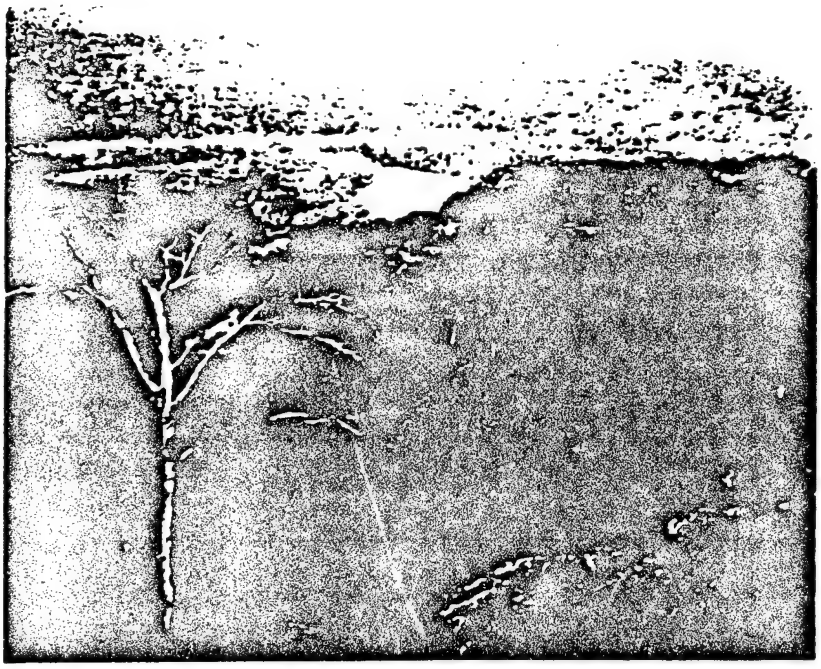


Fig. 33 Terrain toward west from Pidiaque site.

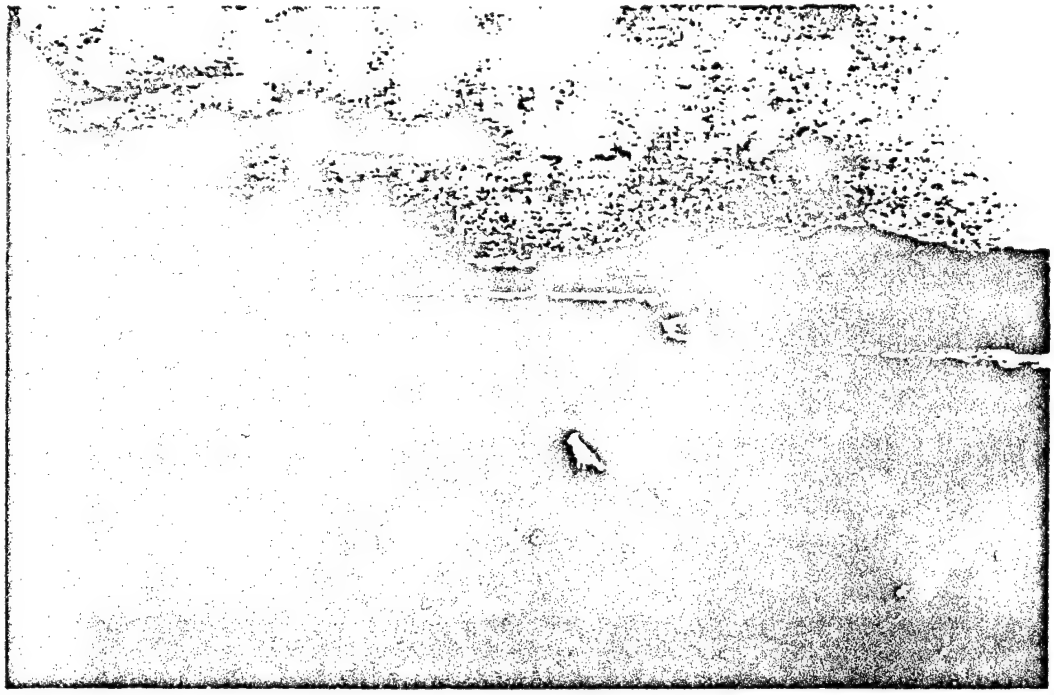


Fig. 34 Terrain toward southwest from Pidiaque site.

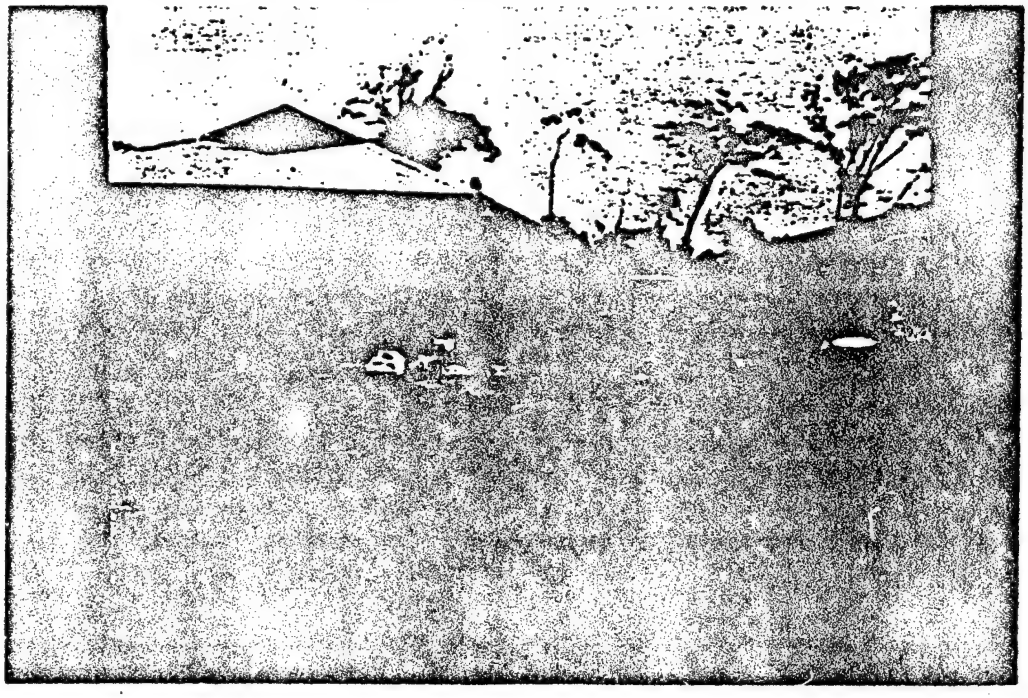


Fig. 35 Sampling at Pidiaque site.

Albrook-Road End (Special Site #16). The Albrook-Road End site (not pictured) is in the Panama Canal Zone at lat. 9°1'17" and long. 79°32'6". The road to the Albrook Forest site (Data Base Site #1) continues for 1 km to a washed-out culvert. A few special samples were collected at this site. Except for the absence of generators, the site is equivalent to the Albrook Forest data base site.

Rio Mar (Special Site #17). The Rio Mar site is in the Republic of Panama at lat. 8°26'10" and long. 80°0'0". The site (Fig. 36) is similar to the Rio Hato-Beach site (Special Site #13) except that the bluff overlooking the beach is higher (20 m).

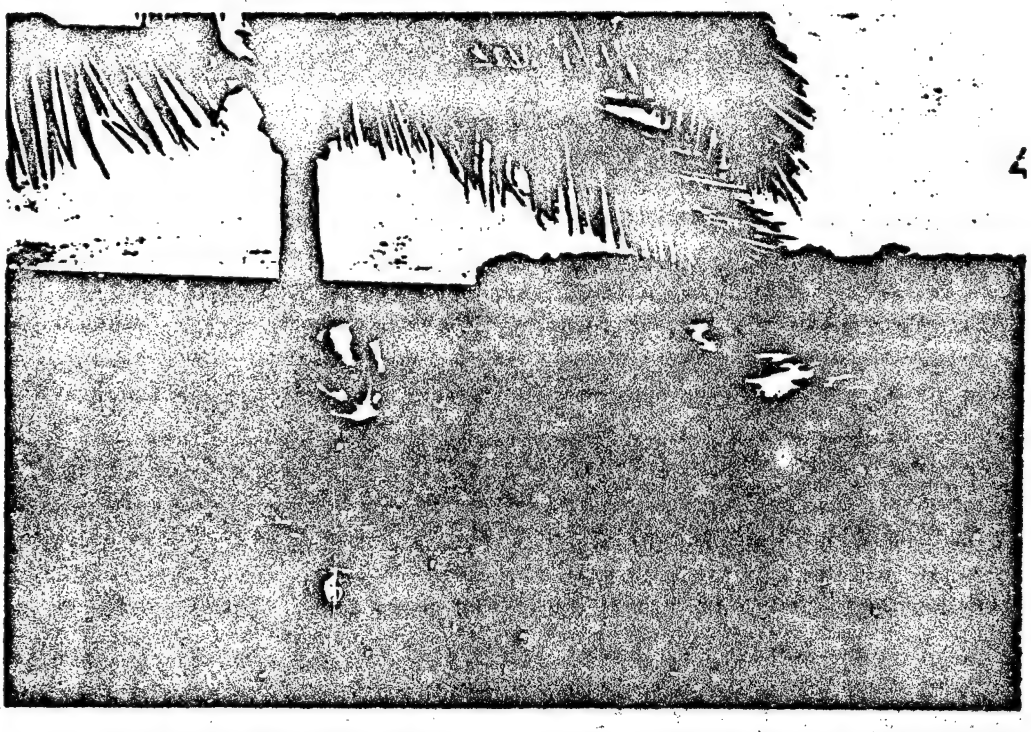


Fig. 36 Special Site #17 (Rio Mar).

Barbados-East Point (Special Site #18). The Barbados-East Pt. site is on Barbados Island at lat. 13°9'16" and long. 59°28'22". The area is a flat shelf of fossil coral rock (Pleistocene) with minimal soil cover (Fig. 37). The sampling point was near the 8-m East Pt. meteorological tower (Fig. 38), built during the 1968 BOMEX I Study [60].

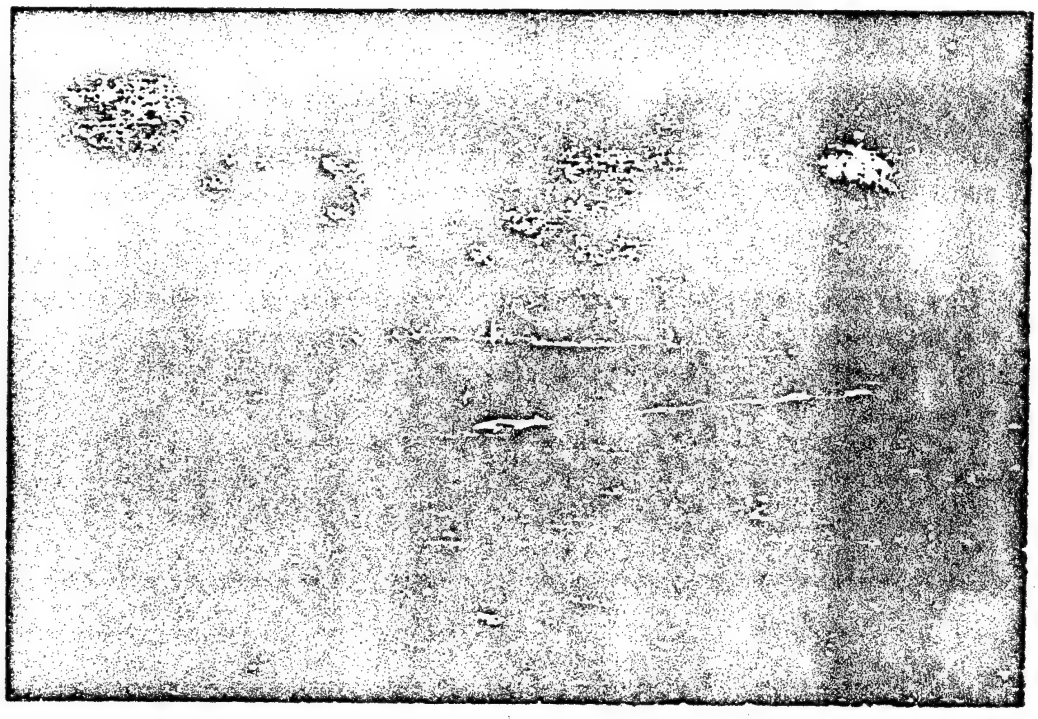


Fig. 37 Special Site #18 (Barbados-East Pt.).

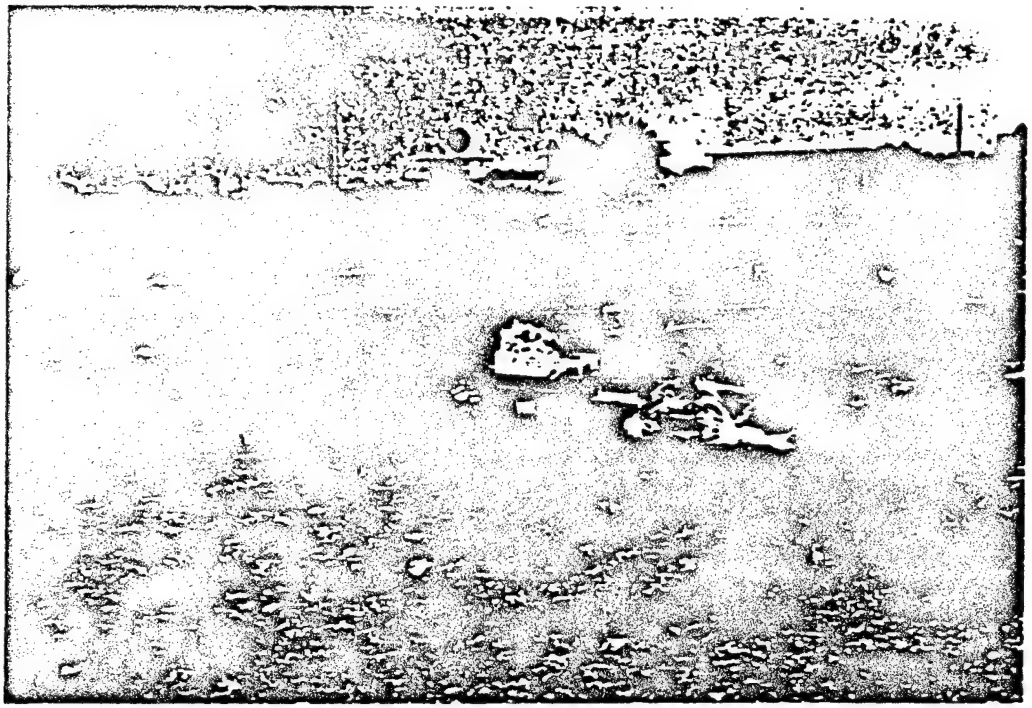


Fig. 38 Sampling at Barbados-East Pt. site.

Barbados-North Point (Special Site #19). The Barbados-North Pt. site is on Barbados Island at lat. 13°19'54" and long. 59°36'49". The site is on the grounds of the North Point Surf Resort and is similar to the East Pt. site (Special Site #18) except that the surf is heavier. Sampling was conducted midway between the edge of the coral rock (Fig. 39) and the building (Fig. 40).

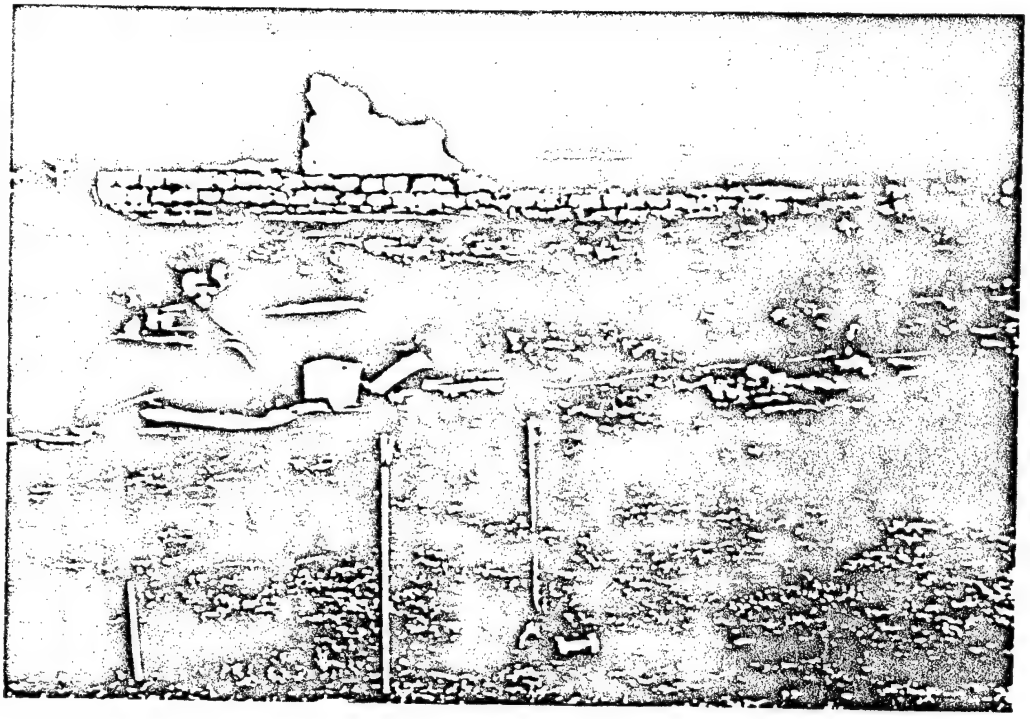


Fig. 39 Special Site #19 (Barbados-North Point).

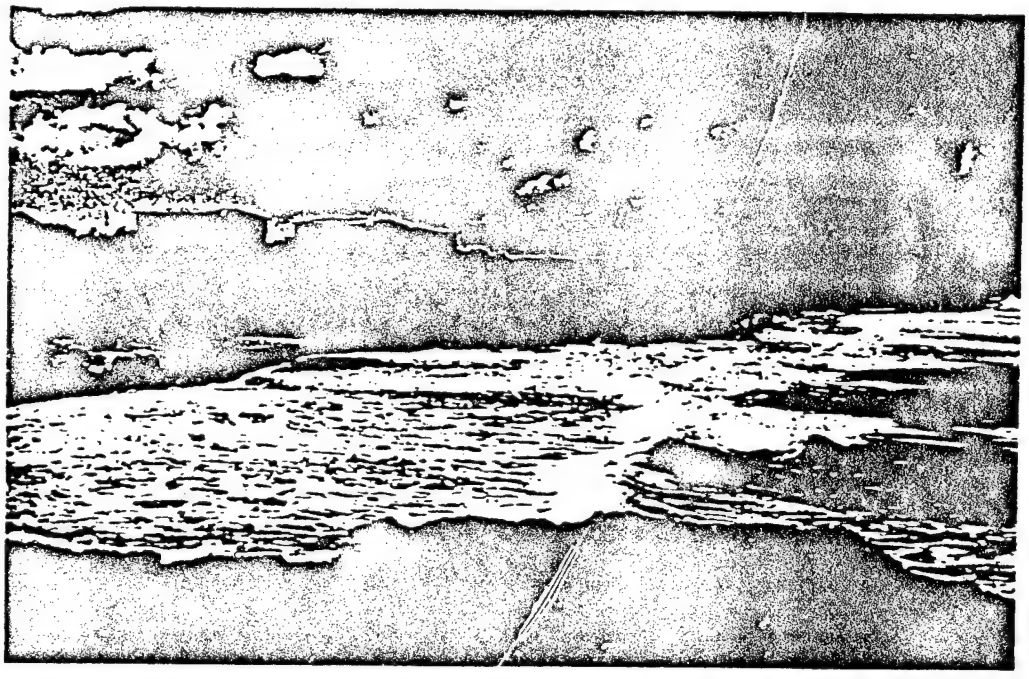


Fig. 40 North Point Surf Resort, Barbados.

Soskatupo (Special Site #20). The Soskatupo site is in the Republic of Panama at lat. 8°55'34" and long. 77°43'18". The site is on the top of a hill on the island of Soskatupo, one of the San Blas Islands on the Caribbean side of the Isthmus. Elevation at the site is estimated at 70 m; access was by helicopter. This site was used as a meteorological station by the Atlantic-Pacific Interoceanic Canal Study Commission during its study of Route 17 for a sea-level canal.

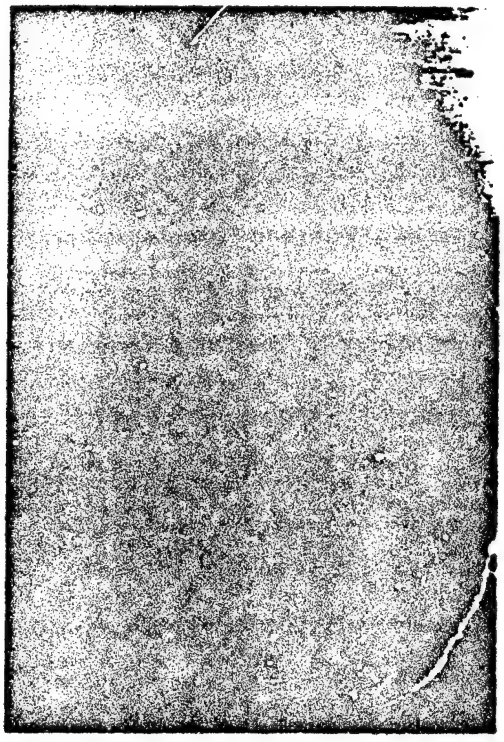


Fig. 41 Special Site #20 (Soskatupo) on Soskatupo Island.

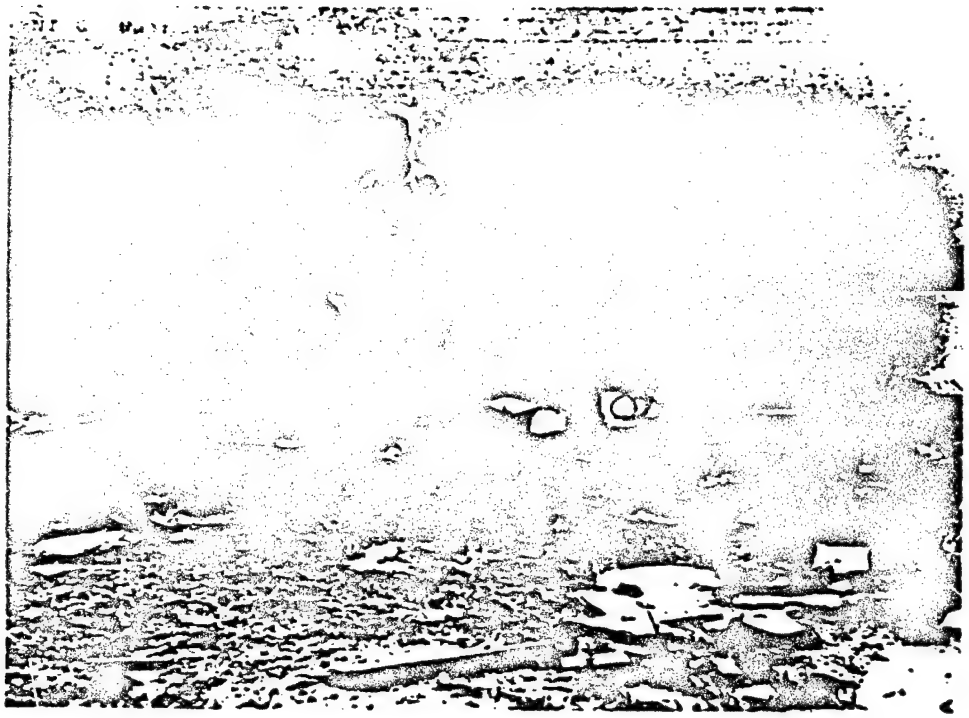


Fig. 42 Sampling at Soskatupo site.

Agua Salud (Special Site #21). The Agua Salud site is in the Panama Canal Zone at lat. 9°11'47" and long. 79°48'2". A 46-m walk-up tower (similar to those at Albrook Forest and Chiva Chiva Data Base Sites #1 and #2) was erected at the site. The forest at this site is intermediate in type between the semideciduous forest at the Albrook Forest site (Data Base Site #1) and the tropical evergreen forest at Coco Solo (Special Site #14). Elevation is 80 m.

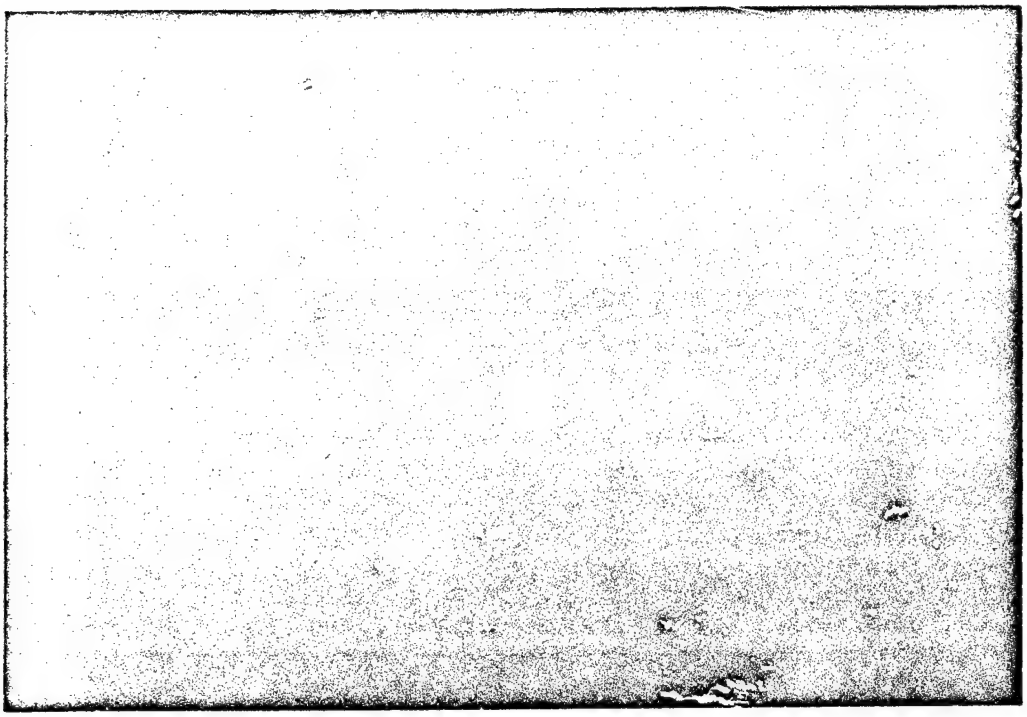


Fig. 43 Surroundings at Special Site #21 (Agua Salud).

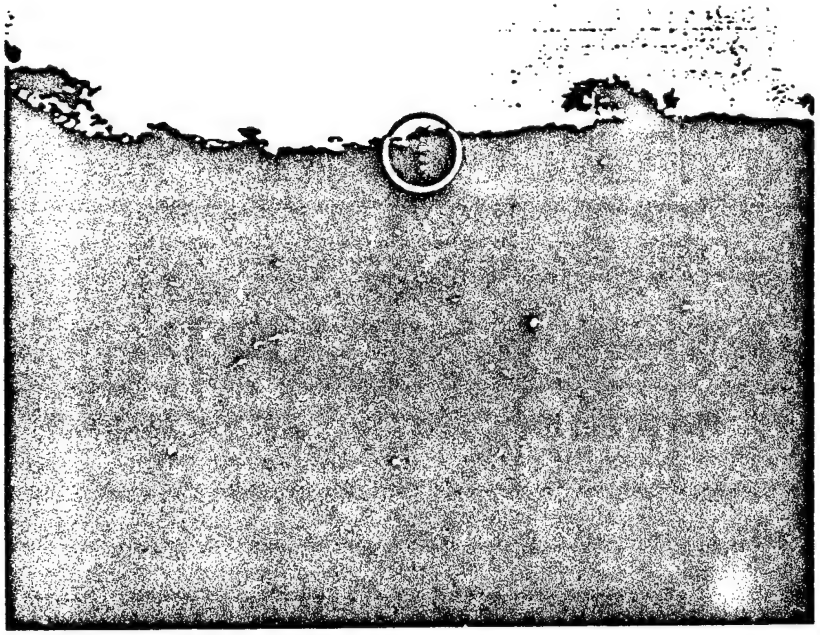


Fig. 44 Tower at Agua Salud site (circle).

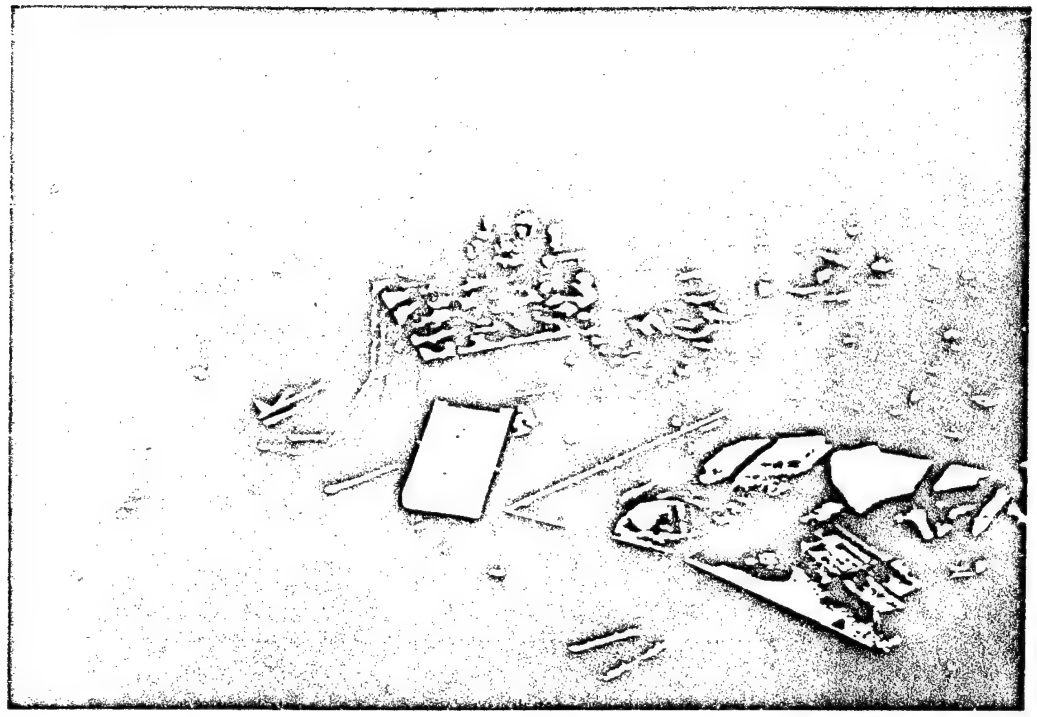


Fig. 45 Sampling at base of tower, Agua Salud site.

Galeta Point (Special Site #22). The Galeta Pt. site is in the Panama Canal Zone at lat. 9°24'11" and long. 79°51'40" and is the site of a Smithsonian Institution marine research station (Fig. 46). A few special samples were collected here.

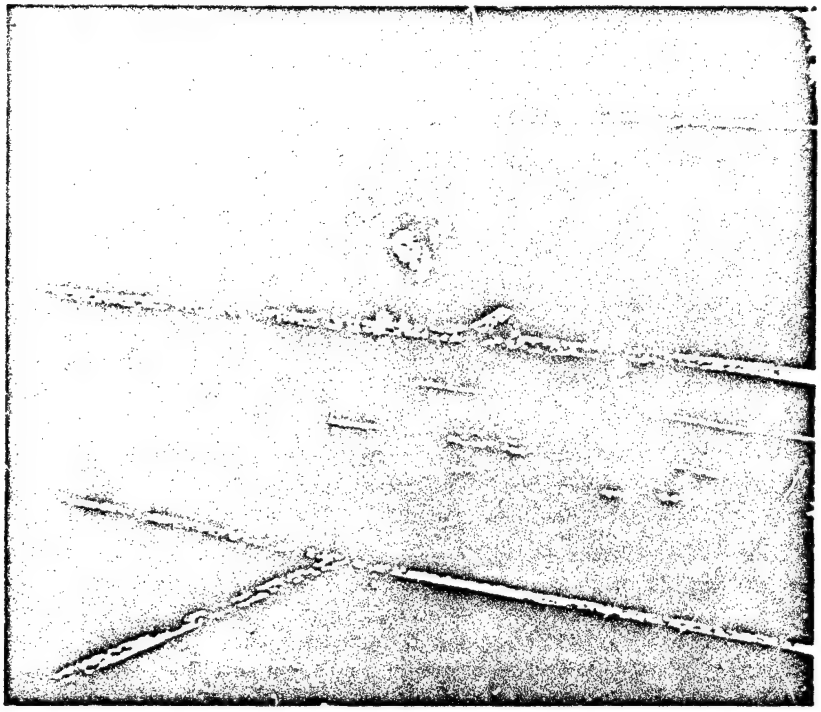


Fig. 46 Sampling at Special Site #22 (Galeta Pt.).

Madden Preserve (Special Site #23). The Madden Preserve site is in the Panama Canal Zone at lat. 9°6'12" and long. 79°37'4", in a biological preserve established at the point where the Las Cruces Trail crosses the Trans-Isthmian Highway. Elevation is 160 m.

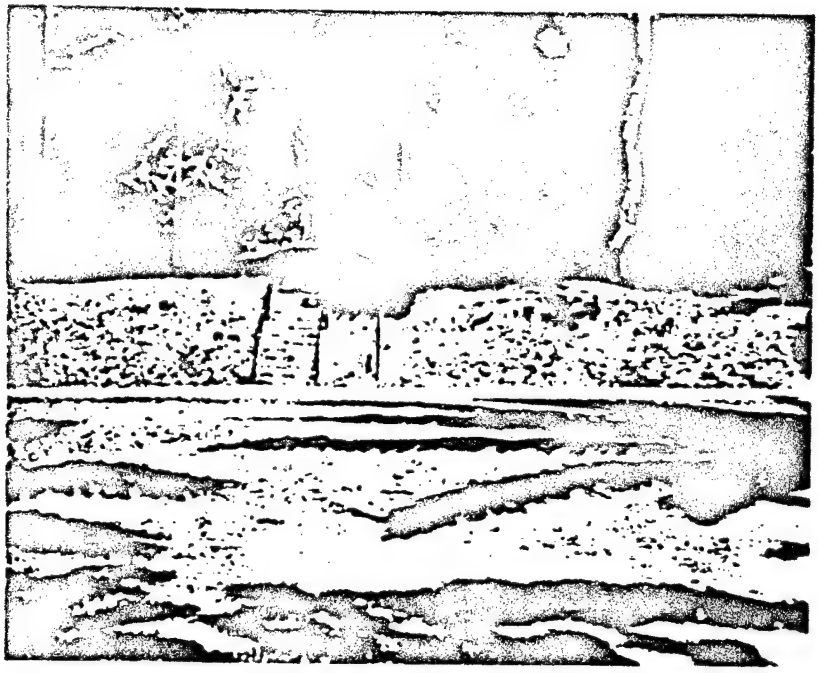


Fig. 47 Primary growth forest at Special Site #23 (Madden Forest Preserve).

Fig. 48 Sampling at Madden Forest Preserve site.

Miraflores Laboratory (Special Site #24). The Miraflores Laboratory site (not pictured) is in the Panama Canal Zone at lat. 8°59'52" and long. 79°35'25". The laboratory is immediately adjacent to the Miraflores Locks. Occasional special samples were collected in the field of tall grass (to 2 m) covering the area to the east of the site. Elevation is 10 m.

S. S. Advance II (Special Site #25). A special series of samples was collected by C. E. Decker and J. R. Smith [60] on the S. S. Advance II cruise, which was a part of the Barbados Oceanographic and Meteorological Experiment (BOMEX). The Advance II (Fig. 49) belongs to the Cape Fear Technical Institute, Wilmington, N. C.

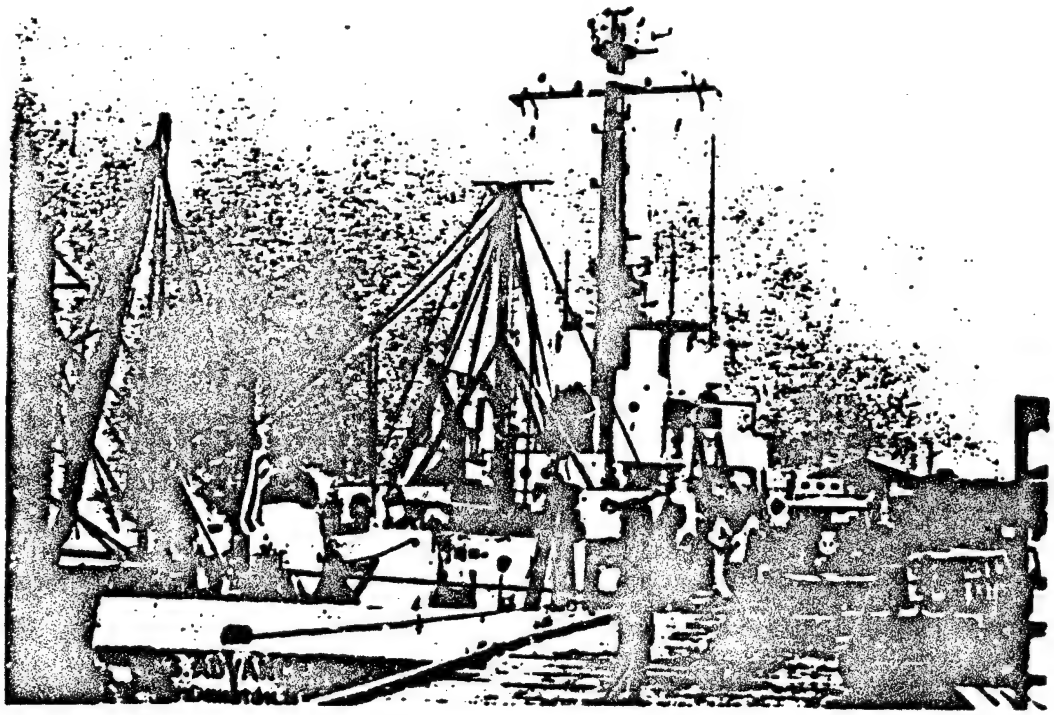


Fig. 49 Special Site #25 (S.S. Advance II).

Soufriere, St. Lucia (Special Site #26). The Soufriere site is on St. Lucia Island in the Caribbean Sea at lat. 13°50'8" and long. 61°2'48". An active fumarole (Fig. 50) is accessible by road from the town of Soufriere. Samples were collected on a cocoa plantation by the side of the road leading to the fumarole (Fig. 51), and also in the fumarole proper (Fig. 52). Sampling elevation varied from 200 to 300 m.

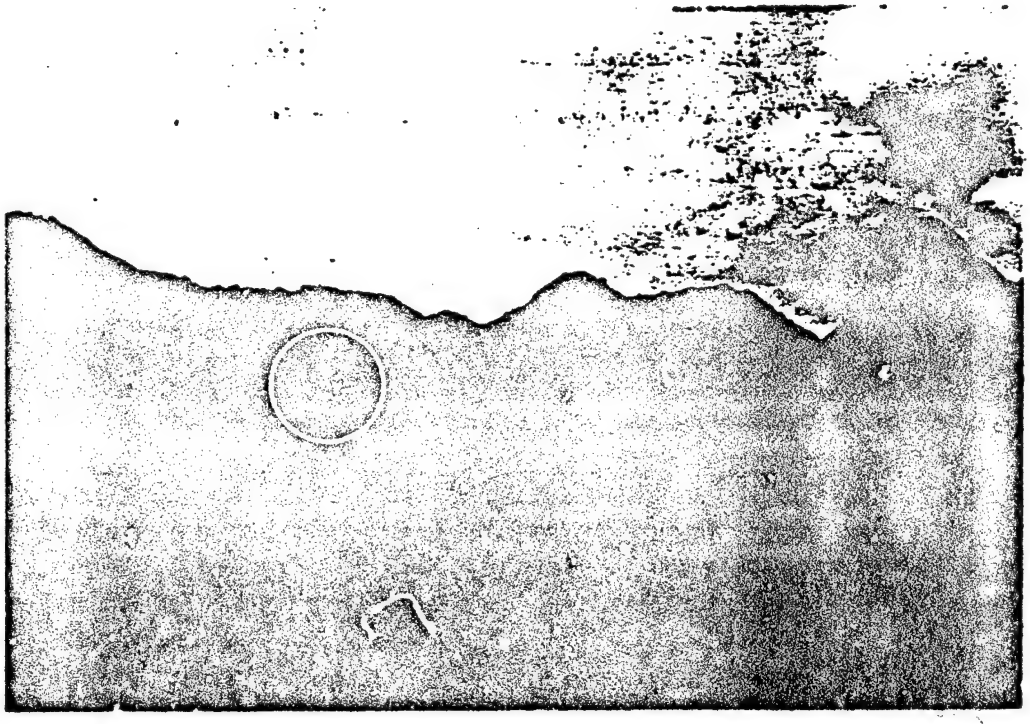


Fig. 50 Fumarole (circle) at Special Site #26 near Soufriere, St. Lucia.

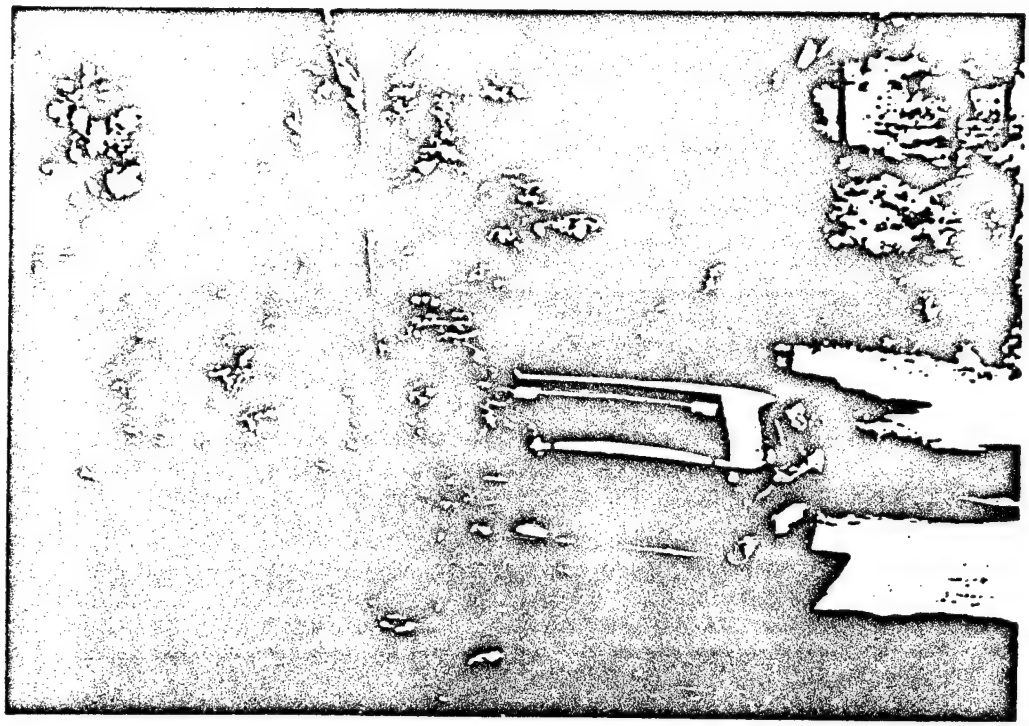


Fig. 51 Sampling on road to fumarole, Soufriere site.

Fig. 52 Sampling at fumarole, Soufriere site.

C. Aerial Sites

The reference points used to describe vertical (aerial) sampling sites are shown in Fig. 53. Sampling point A1 (over Brujas Island) is off the Caribbean shore of the Isthmus in the vicinity of Ft. Sherman, where maritime air from the Caribbean impinges on the Isthmus. Area A2 is the Panama City-Chepillo area of the Bay of Panama (Pacific side of the Isthmus); air at this point has traversed the Isthmus. Area A3 is the vicinity of the southern tip of del Rey Island (Pearl Islands) in the Bay of Panama; air at this site has crossed an open body of water after passing over the Isthmus. Area A6 is the Pidiaque site in the Darien area of the Isthmus; this region provided samples of air which had traveled over a completely nonurbanized portion of the Isthmus. Area A7 is over Soskatupo Island on the Caribbean side of the Isthmus. Details of the sampling patterns are described in [20].

Brujas Island (Aerial Site #1). The Brujas Island flight path is shown in Fig. 53 as A1. The Ft. Sherman-Colon complex is the only possible important source of pollution in the area. At all times during sampling this complex was either 5 km downwind or lateral to the flight pattern.

Chepillo Island (Aerial Site #2). The Chepillo Island flight path is identified as A2 in Fig. 53. Flights were made between the urban complex of Panama City and the Pacific-Canal portal, and smoke plumes to the north of Chepillo Island from agricultural burning on the mainland.

Del Rey Island (Aerial Site #3). The del Rey Island flight path is shown as A3 in Fig. 53. The circular flight path was over the extreme southern tip of the peninsula on the south end of the island. Del Rey is the southernmost major island in the Pearl Islands.

Panama City (Aerial Site #4). The Panama City flight was a circle 1 km in diameter over the center of the city; it is shown as A4 in Fig. 53.

Madden Dam (Aerial Site #5). The Madden Dam flight path was a circle 1 km in diameter over Madden Dam, and is shown as A5 in Fig. 53.

Pidiaque (Aerial Site #6). The Pidiaque flight path is shown as A6 on Fig. 53. The circular path was over the Pidiaque Special Site #15, located on the top of the hill overlooking the Sabana River (southwest) and the Darien Forest (northwest).

Aerial Site #6a. During one flight, several samples were collected at 1,828 m early in the flight from Pidiaque to Soskatupo. This is shown on Fig. 53 at A6a. Samples from this flight are grouped with Pidiaque samples.

Aerial Site #6b. Samples were also collected during the latter part of post-refueling flights from the Canal Zone to Pidiaque; this path is shown as A6b on Fig. 53. These samples are classed as Pidiaque samples since they all represent air on the leeward side of the Isthmus.

Soskatupo (Aerial Site #7). The Soskatupo flight path, A7 on Fig. 53 was an oval pattern on the windward side over Special Site #20, Soskatupo Island.

Aerial Sites #7a and #7b. These flight paths are shown in Fig. 53, as A7a and A7b. Samples were collected during refueling flights from Soskatupo to the Canal Zone. The flight to Albrook was modified so that samples could be collected over the windward coat of the Isthmus. The samples from these flights are listed as Soskatupo samples.

Barbados (Aerial Site #19). Samples were collected on selected flights during NCAR's Barbados Experiment [60]; the flight path is shown in Fig. 3 and is described in [61].

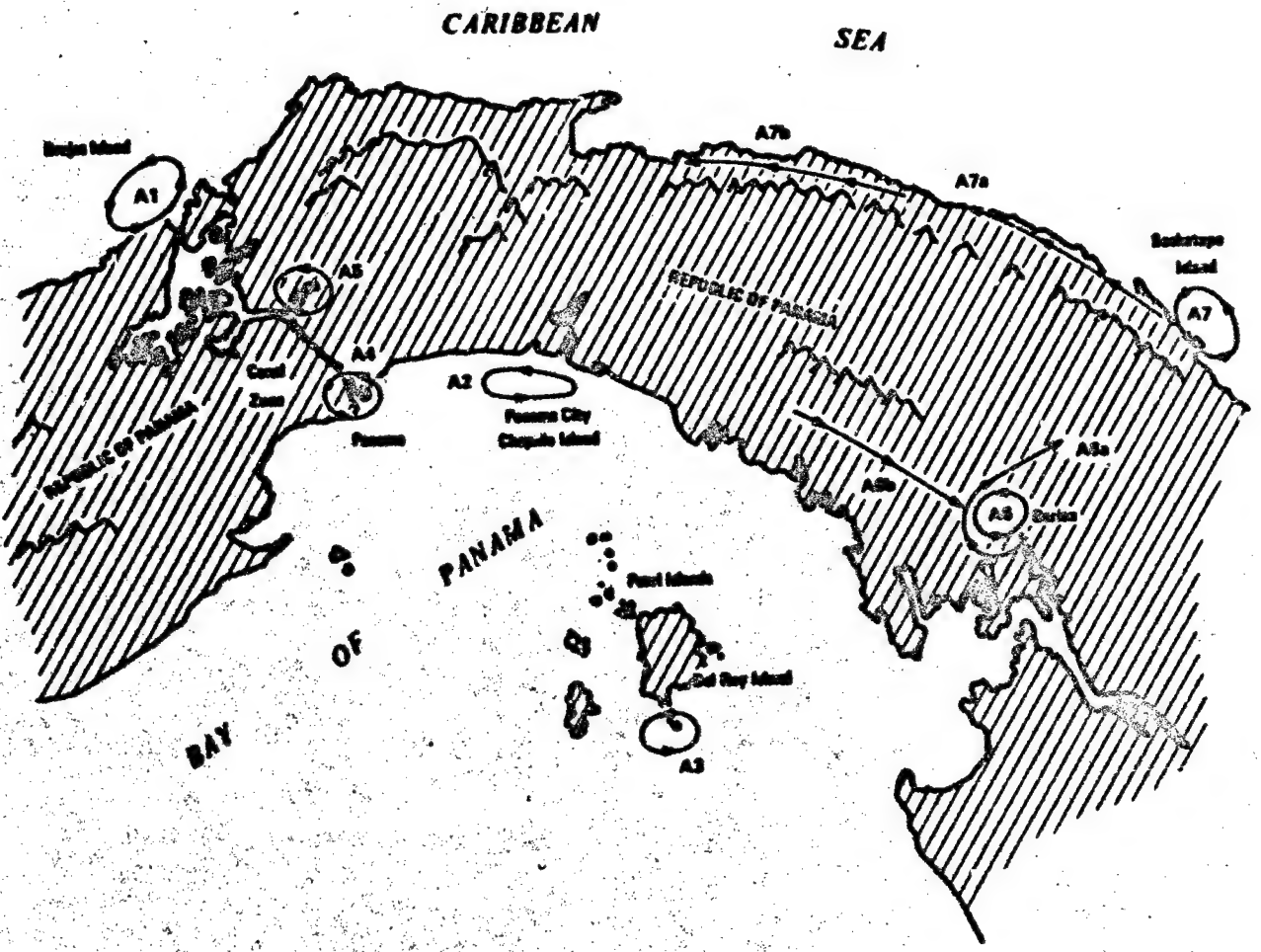


Fig. 53 Aerial sampling sites and flight paths.

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